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RECENT INVESTIGATIONS ON THE EPIDEMIOLOGY OF HUMAN ASCARIASIS*

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The use of certain new methods in field investigations in the last five years has made possible important additions to our knowledge of the epidemiology of human ascariasis. Earlier field studies have usually consisted of surveys to determine the incidence of this parasite in some particular area. The reports of such studies have sometimes included observations, often rather casual, on the habits of the people involved and speculations, often with little basis in actual fact, on possible sources of infection. In the summer of 1926 as part of the researches of an expedition to Panama the ascaris problem was attacked by a combination of the dilution egg counting method and a technic for isolating parasite eggs from the soil. The results were so significant that the same methods have since been used in the United States in field investigations in Virginia, Tennessee and Kentucky. Other investigators have employed them in studies elsewhere in the United States and in other parts of the world. In the present paper these methods will first be discussed and the advances in our knowledge of the ascaris problem that have been made by their use will then be summarized.

METHODS USED IN MAKING EPIDEMIOLOGIC STUDIES ON HUMAN ASCARIASIS

To illustrate the methods employed in the recent investigations on human ascariasis the procedure followed in studying this problem in a small population unit such as a village will be outlined. The first move must be the securing of the cooperation of the people, since it is obviously impossible to make any adequate study of a group that is hostile or only half-hearted in its support of the work. Information can be collected as convenient during the course of the investigation on such general matters as yearly range of temperature, rainfall, soil, drainage, occupation, general habits and customs, group sanitation, and source of

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water supply. The first specific step in the study is made, however, in the collection of samples for fecal examination. The best way to examine a real cross section of a population group is to make a house to house census and to distribute the containers by families. Often the more rapid method of examining schools will give the information desired. It is very important to get all the necessary data about the individuals at the time their samples are collected and every precaution must be taken to keep the samples from becoming mixed.

The next step is the examination of the samples by the dilution egg counting method (Stoll, 1923; Stoll and Hausheer, 1926). One count only is made from each sample since it has been found for both hookworm and ascaris that in a group of any considerable size the picture of infestation is the same with one count as when the average of two is used (Cort, Otto and Spindler, 1930: 6-7; Sweet, 1929: 239-240). Since a well-trained technician can take care of all the work connected with the examination of 35 to 50 samples in a day it is possible to pile up the numbers rather rapidly.

When the egg counts are completed, the results are analyzed to determine the distribution of infestation by age, sex, family or on any other basis suggested by the make-up of the particular group. The results of this analysis make it possible to pick out particular families or other groups for which intensive environmental studies will be of interest. Usually families with heavy infestations are compared with those nearby that are negative or lightly infested. Also families with different environmental conditions or different combinations of parasites are chosen for further study. Experience has shown that the more careful the consideration given to the analysis of the egg counts the more profitable will be the environmental studies.

The environmental studies are chiefly concerned with the individual families although schools, churches and other places in the community that might be involved in the spread of infection should not be neglected. In preparing for the inspection of a family the egg counts of its members with the other information available is lined up on a specific family blank. To this is attached one of the environmental study blanks on which is outlined the principal information desired. When a family is approached the adult member who happens to be at home is questioned on such points as length of residence, previous residence, source of water supply, presence and use of privy, treatment of children for worms, passage of worms by children, general health and other things that may be of help in interpreting the situation. Whenever possible all the children are lined up for inspection and are sometimes given a short physical examination. When some arrangement is possible for free treatment this can be used as a very effective entering wedge.

After all the information possible has been obtained by questioning the inspection of the premises proceeds. Such points are noted as source and possible contamination of water supply, character of house and other buildings, amount of vegetation in the yard, presence of domesticated animals, general appearance of thrift or shiftlessness, and personal and household cleanliness. This general survey is followed by a specific study of the excreta disposal of the family. If a privy is present it is carefully inspected for cleanliness and use. Then an intensive search is made for evidence of soil pollution in the yard, barns, garden and adjacent areas. Often the people themselves will lead the inspectors to the pollution spots and will give information on the habits of the children. The location of pollution spots when considered in connection with the play and work habits of the family often suggests probable sources of infection. Since a single inspection gives only the situation for that particular day, it is important to try to get the people to give information on the regular soil pollution habits and whenever possible to make later visits.

In addition to the inspections the method for isolating parasite eggs from the soil first devised by Caldwell and Caldwell (1928) has been extensively used to find the exact places where ascaris eggs are present in the environs of the houses.* Samples of soil for examination can be taken from the floors, from the spaces under the houses, from the dooryards and other suspected situations. Places for sampling are usually chosen, where the habits of the family, such as the play of the children, would bring them into closest contact with the soil. The most interesting results obtained by this method have been the finding of eggs in the soil in places where human stools were absent and in some cases even where there were no traces whatever of soil pollution on the whole premises at the time of the inspection. In such situations results obtained by the egg isolation method supplement very effectively the evidence from inspections on sources of infection.

* Since this technic has not yet come into any general use it will perhaps be of value to outline it using the description given by Spindler (1929): "A pint or more of soil is collected from a suspected spot by sweeping or lightly scraping the surface of the ground over a large area. In the laboratory this sample is thoroughly crushed and mixed and a representative five to ten gram portion placed in a 50 cc. centrifuge tube and treated for an hour with 10 cc. of 30 per cent antiformin solution. It is quite imperative, in this process, that the mixture be given frequent thorough stirrings to allow the antiformin to act on every particle of soil. If this is not done many eggs will remain adhering to the soil particles and will not be removed in flotation. When sufficient time has elapsed for the eggs to become freed from the soil the tubes are filled with sodium dichromate (specific gravity 1.35), thoroughly shaken and then centrifuged at 1,000 revolutions per minute for one or two minutes. The eggs are then looped from the surface of the dichromate to a microscopical slide by means of a small vial or the open end of a glass tube. They are then counted and classified according to the stages of development to which they have attained."

After all the environmental studies of the selected families are completed the information obtained together with the egg count data are further analyzed. Usually additional inspections are needed to check up specific points. By a sufficiently thorough application of the procedure described above a fairly satisfactory picture can finally be made of the distribution of ascaris infestation and the factors influencing its spread in the particular group under consideration.

In the discussion that follows the data on the epidemiology of ascariasis obtained from the environmental studies by inspection for soil pollution and the examination of soil samples by the egg isolation method will first be taken up. Following this the information from the egg counts that have been made from different parts of the world will be considered.

EVIDENCE ON SOURCES OF INFECTION OBTAINED FROM SOIL POLLUTION AND SOIL INFESTATION STUDIES

Much information on sources of ascaris infection has been obtained from the study of the habits of excreta disposal of infested groups and by the examination of soil by the egg isolation method. Brown's (1927) studies of sources of infection near the houses in Panama were very significant. In families heavily infested with ascaris he found soil pollution in the dooryards and even on the dirt floors of the houses themselves. Soil isolations revealed ascaris eggs, many of them in the embryonated stage, in the sweepings from the dooryards and from the mud floors of the huts. He came to the conclusion that eggs within and near the houses must be an important source of ascaris infection in Panama.

These findings naturally directed attention to the immediate surroundings of the houses as sources of infection. Similar conditions were found to be common in certain rural areas in southwestern Virginia where gross soil pollution usually attributed to the youngest children was frequently found in the yards of families with ascaris infestation (Cort, Otto and Spindler, 1929 and 1930). Here a common place for depositing the stools was the space under the houses where the children played. Repeated examinations of soil samples from the premises of such ascaris families showed a concentration of eggs near the houses, even on the exposed hard packed soil of dooryards and paths. Later studies of a large series of families in widely separated areas in the mountain regions of Tennessee further emphasized the importance of dooryard pollution (Otto, Cort and Keller, 1931). The same sources of infection were also found to be important in a series of unpublished investigations made by Dr. G. F. Otto in the summer of 1930 in eastern Kentucky. There is also a considerable amount of evidence that in certain regions in China (Cort and Stoll, 1931), as for

example in the rural areas near Chefoo and in villages of the Canton delta, dooryard pollution by young children is an important source of infection. On the other hand families where soil pollution is present may be negative or only very slightly infested with ascaris if the stools are deposited away from the immediate vicinity of the house. In fact a considerable series of families were found both in Panama (Cort, Stoll, Riley and Sweet, 1929) and in the United States without any privies whatever but with no ascaris infestation of any significance. Such families were usually found to be either without young children or at least with no evidence of pollution near the houses. It evidently requires rather gross pollution near the houses to build up heavy ascaris infestations. Where this is found the soil in the dooryards, along the paths and under the houses becomes seeded with enormous numbers of infective eggs. These eggs can easily be carried into the houses and there contaminate the food or articles handled by the people. An even more important source of infection appears to be the constant playing of the youngest children on the contaminated soil of the yard, where they easily get the eggs on their hands and transfer them to their mouths.

While the abundant evidence of the importance of sources of infection near the houses has been the outstanding feature of the recent field studies on ascariasis, this finding does not of course exclude the possibility of a wide variety of other methods. In a number of cases children of families, where no pollution was found on the premises, appeared to have obtained their worms from the yards of ascaris families. Community sources of infection have also been demonstrated such as the premises of vacant buildings and the areas around unsanitated schools. In one of the groups studied in Virginia there was an excellent example of a community source of infection at an old abandoned church where the children especially those of pre-school age were accustomed to play. Numbers of stools were found at every visit both on the floor and in the space underneath. Also embryonated ascaris eggs were isolated in quantity from these situations. This old church was, therefore, a center for the dissemination of ascaris which probably had a considerable part in the building up of the infestations of the children of the neighborhood (Cort, Otto and Spindler, 1930; 40).

Emphasis on the school as a source of infection was made in the report of family studies in Tennessee (Otto, Cort and Keller, 1931). In some of the more isolated counties of this state the rural schools have little if any sanitation. For example at one new school with two teachers and about 65 pupils no privies were provided for either boys or girls. A search for soil pollution revealed dozens of stools in a rather dense wood about 25 yards from the school where the girls had play houses. On the other side of the school pollution areas visited by the boys were

also found. That this is not an isolated case was shown by the statement of the sanitary inspector of this county that only 18 of the 60 rural schools had sanitary privies and that at many of them gross soil pollution occurred. In this particular county a sanitary program had been in operation for two years but it had been impossible for the health officer to convince the majority of the hard headed business men who made up the school board, that money for school privies was a proper expenditure, since they considered them to be new fangled luxuries. This particular county is no worse than many others since rural schools entirely without privies or with improper sanitation are found all through the mountain regions of the southeastern United States. Such situations indicate that in many places the schools are not only failing in their opportunity to teach the simplest rudiments of sanitation, but are themselves important centers for the dissemination of parasitic worms.

The possibility of ascaris infection from drinking water has been suggested even by the earlier workers. While there is no reason to believe that infection from such sources does not often occur it is very difficult to actually demonstrate it. Perhaps the best evidence that implicates drinking water comes from the studies of Chandler in India (Chandler, 1925, 1926 and 1928). Here it seems probable that in certain places the ascaris infestations are chiefly acquired from drinking the water from shallow pools called "hulas" which are polluted by defecation on their banks or even into the water itself. In the reports of the field studies in Panama and the United States there is not a single case in which the evidence implicated the water supply and in most of the communities it has been possible to rule out the drinking water as a source of infection.

Where human excrement is used as fertilizer other sources of ascaris infection are produced. In fact this parasite is extraordinarily prevalent in China, Japan and Korea where this custom is almost universal. Yoshida (1923, 1925) attributed the very high incidence of ascaris in Japan to the methods of fertilization of vegetables that are eaten raw, Mills (1927) has also suggested that viable ascaris eggs on pickled turnips and cabbage, which are eaten raw with almost every Korean meal, offer the best explanation of the widespread prevalence of this parasite. This theory explains why there is so little difference in the incidence in different classes of people in his series regardless of their economic condition, education or attention to personal hygiene. Yoshida (1923) further made the statement that he has very often found on the leaves of vegetables viable ascaris eggs which stuck so firmly that the usual amount of washing did not remove them from such vegetables as radishes and turnips. Other investigators in the Orient have also reported the finding of ascaris eggs on vegetables (Iwahashi, 1923;

Isobe, 1925). It has further been suggested that the handling of human feces in its preparation as fertilizer and the scattering of eggs widely with the distribution of night soil on the fields, might serve to distribute this parasite widely in the population (Cort and Stoll, 1931). It is significant in this connection that in regions where human excrement is used as fertilizer there is a higher incidence and heavier infestation in adults than in those countries like Panama and the United States where this custom is not found. The heaviest average infestation which has been reported up to the present time by the egg counting method is from the rural population of the Canton delta region in China where there is a combination of a subtropical climate with a high annual rainfall, soil pollution by children and the use of human excrement as fertilizer (Cort and Stoll, 1931).

INFORMATION ON THE EPIDEMIOLOGY OF ASCARIASIS FROM EGG COUNTS

The Family as the Unit of Ascaris Infestation

In those regions such as Panama and the mountain sections of the southeastern United States where soil pollution near the houses appears to be the most important source of ascaris infection, it is clearly shown from the egg counts that the family is practically always the unit of infestation. This is true in community groups as well as in isolated rural areas. In fact one of the first things which called attention to sources of infection in the dooryard was the finding of negative or lightly infested families living close to those that were heavily infested. All the reports of egg count examinations where analysis has been made according to families show some in which the worm burden of all or most of the members is very heavy. These have been called ascaris families and from their study important information has been gained on the factors favorable for the building up of heavy infestations. Because of this relation it becomes important to analyze any series of egg counts for ascaris according to families and if the family proves to be the unit of infection to center the study of environmental factors in it. Much of the evidence on sources of infection discussed above has come from the study of individual families in which the infestation of the members was known from egg counts. There are in addition, however, certain general relations that have been learned from the analysis of the egg counts of larger groups. These will be discussed in the sections which follow.

SIGNIFICANCE OF NEGATIVES IN EGG COUNT SERIES

An analysis of the make up of the negatives for ascaris in the egg count series available in the literature will be considered first. In the

2,247 examinations from Panama 49 per cent were recorded as negative. It is rather surprising to find such a large group of negatives especially as in the same series only about 10 per cent were negative for hookworm. A considerable proportion of the ascaris negatives is accounted for by the presence in the series of whole families either entirely negative or with a few very lightly infested members, obviously living under conditions not at all favorable for the spread of ascaris.

Of even more interest are the negatives in groups with the maximum exposure to infection. For example in 40 families of 259 individuals also from the Panama series that had an average egg count of over 30,000 eggs per cc. there were 50 individuals or 19 per cent recorded as negative. A somewhat comparable group from the Virginia series is made up of those families composed of 552 individuals in which there was an ascaris infestation of considerable size. In this group there were 137 or 25 per cent negative. How then will we explain this considerable percentage of negatives in these two series of ascaris families, where sources of infection near the houses are probably almost everywhere present? In the first place it was found that the percentage of negatives was much greater in the adults than in the children. For example in the series from Virginia just mentioned the percentage of negatives in the children (0 to 14 years) was 12 while that in the adults was 52. This greater percentage of negatives in adults in heavily infested families appears to be due as will be discussed later to habits that give them less exposure to infection than the children.

The final problem then is to explain the negatives in the young children. There was not the slightest evidence that these negative children except those under two years differed in habits from their brothers and sisters who were infested. Otto (1930) found in a group followed by the egg count over a considerable period that in a number of cases individuals positive at one examination were negative at the next and vice versa. He expressed the view based on this and other evidence that in any group harboring ascaris there is a constant fluctuation in individual infestations due to a spontaneous loss of worms. In other words the finding of a negative case in a child in a heavily infested family probably only means that this individual has recently spontaneously expelled his worm burden, and that reinfection has not yet had time to produce egg laying females.

Series composed of both children and adults with an ascaris incidence of 90 per cent or over are of particular interest. Such groups are found in China as for example that of 890 individuals of all ages examined from the rural districts around Chefoo, in which there were only about 10 per cent negative (Cort and Stoll, 1931). Here the suggestion is made that the adults have an exposure to infection not

present in Panama and the United States due to the use of human feces in fertilizing crops used for food.

SIZE OF EGG COUNTS

Certain points of interest on the size of egg counts come out of the analysis of the egg count series that have been reported. Ascaris egg counts vary from those representing the egg output of a single female worm to those truly enormous in size. The highest count in the literature is 1,001,200 eggs per gram in a female, of the 15 to 19 year age group living in the Canton Delta region. In the total Panama series (Cort, Stoll, Riley and Sweet, 1929) there were 32 individuals with counts over 200,000 eggs per cc. with an average of 345,000 eggs per cc., which probably represents an average infestation of somewhere around 300 worms per individual. In one small group of 337 examinations in the Canton Delta 10 individuals are listed with counts over 300,000 eggs per gram. These high counts in a small proportion of the cases correspond to the small number of extremely heavy ascaris cases which are found reported in the literature in which several hundred or even a thousand worms have been obtained from a single individual either by treatment or at post mortem examination.

Another striking thing that has been found out about ascaris, wherever it has been studied by the egg counting method, is the concentration of a very large percentage of the worm burden in a small number of individuals. In the Panama series 99 cases, only 4.5 per cent of the individuals examined, had a total egg count that was 49 per cent of that of the whole group. In the southwestern Virginia series 6.1 per cent of the males had 50.5 per cent of the worm burden and 6.4 per cent of the females had egg counts equal to 56.3 of the total count in the females. Nor do the peculiar conditions of infestation in China alter this relationship. For example 6.7 per cent of the 1016 individuals examined from the Canton Delta had 51.3 per cent of the total worm burden of that group as measured by the egg count. What these figures appear to mean is that it is a characteristic of ascaris infestations for about 50 per cent of the worms to be concentrated in about 5 per cent of the total group. It can be suggested, therefore, that the combination of factors necessary to build up the extremely heavy ascaris cases or to produce real ascaris families is only rarely met with. In other words in spite of the ease with which ascaris spreads it requires conditions of very gross soil pollution and very poor personal hygiene to produce the heavy infestations. Facts obtained from the environmental studies of heavily infested families support this view, since soil pollution by such families is almost always found to be very gross and concentrated near the houses and the standards of personal hygiene are almost invariably very low.

AGE AND SEX DISTRIBUTION OF ASCARIS INFESTATION IN POPULATION GROUPS

Perhaps the most important information that is obtained by the analysis of the egg counts of the total groups that have been examined is the distribution of the ascaris infestation according to age and sex. The heavy infestations of children, especially those of pre-school and early school age, is one of the first points that becomes clear. In the Panama series, even after the most liberal reduction of the actual egg counts for stool size (Stoll, 1929), the infestation in the children is very much heavier than in the adults.* The peak of the curve in the males falls in the 5 to 7 year age group and in the females in the 10 to 11 group. Also the average count of the children (0 to 14) is about three times that of the adults (15 years and over). Another point of interest in the Panama series is that the females from 10 to 39 years of age have an average egg count twice that of the males, while beyond 40 years the average is the same in both sexes.

The age distribution of the egg counts from the series from southwestern Virginia is quite similar to that from Panama (Cort, Otto and Spindler, 1930). In fact the ratio of the infestations of the children to that of the adults is much greater. Also in this series the young adult females have about twice as high counts as the males of the same age. This same relation between the ascaris infestations of children and adults, and males and females has also been found in the very large series of egg counts that have been made from the mountain regions of Tennessee and Kentucky, the analysis of which has not yet been published. This type of age and sex distribution appears, therefore, to be associated with conditions where the chief sources of ascaris infection are from soil pollution by the children near the houses. The explanation given for these differences is that the children especially those of the youngest age groups, on account of their playing on the ground of the dooryards and their carelessness in cleanliness and in what they put into their mouths, are much more exposed than the adults to infection. The closer association of women of child-bearing age with

* Stoll (1929) presented figures on the size of children's stools which indicated that the fecal output in the 3 to 4 year age group is only half that of adults and in the 1 to 2 year group only about a quarter. For example three 10,000 eggs per gram counts, basis formed stool, from a two year old, four year old and adult really represent counts of about 2,500, 5,000 and 10,000 eggs per gram respectively. While the actual figures of stool size in the groups over 4 years are not so clearly worked out this author suggests that the adult stool size is reached at about 10 years. This would make it necessary also to discount the counts for individuals in the 5 to 9 age group. Cort, Otto and Spindler (1930:10-11, graph 1) using Stoll's Panama figures as a guide discounted the egg count in the 0 to 2 group 75 per cent, in the 3 to 4 group 60 per cent, in the 5 to 6 group 50 per cent and in the 7 to 9 group 30 per cent. This is of course an approximation and is probably a slightly greater reduction than the available information warrants.

the children and a greater proportion of time spent working in and around the house would account for their having heavier infestations than the men who usually spend much of their time away from home.

It might be postulated of course that the adults become less susceptible to infection as they grow older. It seems difficult, however, to believe that adults are, to any considerable extent at least, less susceptible to ascaris infection than children, since it is known that in certain cases individuals and groups of adults harbor infestations quite comparable to those of children. For example the egg counts of adults in the series from China are much closer in size to those of the children than in those from Panama and the United States (Cort and Stoll, 1931, Table 1). Also of interest in this connection are groups of adults in the China series with unusually heavy infestations (Cort and Stoll, 1931, Table 3). For example the 155 males from 20 to 39 years of age from the village of Kwang Yik Wai in the Canton Delta have an average egg count of 30,920 and a mean for the positive cases of 45,650 which are comparable to those of the most heavily infested groups of children that have been reported. It seems clear, therefore, that when adults have sufficient exposure to infection worm burdens equal to those of children can be built up. These findings, support the view that where adults are only lightly infested in families where the children have heavy infestations the difference is due to differences in exposure to infection rather than to any lack of susceptibility of the adults.

ECONOMIC STATUS AND ASCARIS INFESTATION

In those regions where the chief source of ascaris infection has been shown to be soil pollution near the house, the heaviest infestations are usually found in the poorest, most degraded portion of the population. This is particularly true in a place where the people have been given a considerable amount of instruction in household sanitation. On the other hand in some regions as for example the most isolated rural areas of the mountain sections of the southeastern United States, which are practically untouched by sanitary work, the conditions suitable for ascaris spread were present in the better classes as well as the poorest. Exceptionally people of the lowest type in areas where ascaris is prevalent escape infection. For example practically no ascaris was found in a group of negroes of the poorest most degraded type, who were examined as part of the series from southwestern Virginia (Cort, Otto and Spindler, 1930: 40-41). Repeated inspections showed no soil pollution around the houses of these people, the old dilapidated privies being in constant use. There was also a number of families studied, both in Panama and the United States who had little or no ascaris infestation in spite of the absence of sanitation. A common feature of such families

is the habit of both children and adults of polluting the soil at considerable distances from the houses. This seemed to be the factor that protected them from infection, since nearby families with dooryard pollution had high ascaris egg counts. In fact the suggestion has been made (Otto, Cort and Keller, 1931) that the keeping of the pollution at a distance from the house in the lowlands of western Tennessee is an important factor in the low ascaris incidence of this region as compared with the mountain sections of the state.

Heavy infestations, usually in young children, have been found in the ascaris areas in the United States in families that are in every way above the average of the communities in which they live. Such a family is described in the report of the researches in Tennessee (Otto, Cort and Keller, 1931). This family lived on a large prosperous looking farm in a wide valley with a type of house and barns comparable to those of the better classes of farmers of any region. Their yard was large, with well-kept lawn and shrubbery and there was a good privy about 100 feet from the house. All four of the children from 5 to 9 years of age were infested with ascaris and embryonated ascaris eggs were found in soil samples taken next to the house and under several apple trees in the yard where the children commonly played. Cases of ascaris infestation in children of families of the better class are in fact not at all uncommon in the areas that have been studies in the United States. In such families almost always pollution by young children could be found near to the houses. The fact that the privy was often at a considerable distance and usually not convenient for the use of young children contributed to this situation.

The relation of heavy ascaris infestation to poverty is not so apparent in countries where human excrement is used as a fertilizer. For example Mills (1927) in his series of examinations from Korea found the incidence of ascaris just as high in the wealthier classes as in the poorest people. Ascaris is also prevalent in the better classes in Japan and China. Evidence is available, however, that indicates that the most intense infestation is usually found in the lower classes, where infection from soil pollution habits of children would be an important factor as well as that from eating contaminated vegetables (Cort and Stoll, 1931).

URBAN VERSUS RURAL COMMUNITIES IN ASCARIS INFESTATION

Ascariasis seems to be just as much a disease of urban as of rural populations. Mills (1927) emphasized this in his examinations from Korea, and statistics from cities in Japan and China show the same thing. Much of the infection in oriental cities is evidently due to the eating of contaminated vegetables. In Panama very high ascaris eggs counts were found in the poorer classes of two of the provincial capitals.

In fact one of the highest average counts yet recorded was in a group from Santiago, the capital of Veraguas Province (Cort, Stoll, Riley and Sweet, 1929: 178). Environmental studies showed a great deal of soil pollution in the small yards around the houses. It seems probable that in such situations the crowding produced by city conditions would tend to concentrate the pollution by the children and produce even heavier infestations than in rural districts. Similar conditions appear to be common in poorly sanitated portions of cities especially in tropical and subtropical regions. On the other hand in the United States and most of Europe ascaris is largely a rural problem, because most of the cities of any size have modern sewerage systems and the community life tends to educate the people above the level of soil pollution.

ASCARIS INFESTATION IN RELATION TO TEMPERATURE, MOISTURE, SOIL AND OTHER GENERAL ENVIRONMENTAL CONDITIONS

To get before us a more complete picture of the different factors that influence the distribution of ascaris it will be necessary to consider the relation of climate, soil and certain other general environmental conditions. The eggs of the ascarids have a remarkable resistance to external conditions. An extensive literature has developed on the effect of different factors such as temperature, moisture and various chemicals on the eggs of *Ascaris lumbricoides*. It would, therefore, be impossible even briefly to sum up the numerous experimental studies along this line. A few points will be mentioned, however, which apply very definitely to the distribution of this parasite. Ascaris eggs at different stages of development can withstand freezing temperatures for long periods of time and can survive a severe winter. Eggs have been found to develop to the embryonated stage at a wide range of temperatures, about 8 to 37° C. Of course the rapidity of development and the percentage of the eggs surviving varies at the different temperatures. At the higher ranges the eggs are much more easily killed, since they will not live for any considerable length of time at temperatures of 38° to 40° C. and are killed in a short time when the temperature is raised to 50° C. The eggs of the human ascaris also have some resistance to desiccation and can develop when only a small amount of moisture is present. In this connection it has been shown (Otto, 1929) that eggs air-dried on glass slides will develop in an incubator with a humidity above 80 per cent. In addition the eggs of ascaris can develop normally in high concentrations of certain chemicals, can live for a considerable period under anaerobic conditions and require only a small amount of oxygen for development. This means that almost never under natural conditions would they meet chemical factors unfavorable for their development

and that except in very exceptional situations they would find sufficient oxygen.*

This unusual resistance of the eggs of the human ascaris to external conditions has a profound effect on its geographical distribution and also on its ability to establish and to maintain itself in a variety of situations. Instead of being practically limited to tropical and subtropical areas which have considerable rainfall as is the hookworm, ascaris has a world wide distribution, having been reported in the arctic regions and in countries that have almost desert conditions. The recent studies in the United States have shown that ascaris eggs can develop and persist on the hard packed unshaded soil of dooryards, where the larvae of hookworm cannot develop and where the eggs of trichuris are killed. In fact it is suggested that perhaps the most important factor in the differences in the distribution of the human ascaris and trichuris is the greater resistance to desiccation of the eggs of ascaris and their ability to develop where there is too little moisture for the development of those of trichuris (Spindler, 1929 a and Otto, Cort and Keller, 1931). This means that ascaris is less restricted by climatic conditions than almost any other human parasite. A good example of this is the extremely high incidence and heavy infestation found in the rural areas around Chefoo (Cort and Stoll, 1931) in north China. Here on account of unusually favorable human habits in a region with an annual rainfall between 20 and 30 inches and a long cold winter, an ascaris infestation was found comparable to that of areas in Panama with tropical temperatures and rainfall of about 100 inches a year.

Two instances of the killing of ascaris eggs under field conditions by exposure to direct sun rays have recently been reported. Brown (1927a) found in his studies in Panama that the eggs of this parasite were killed on sandy soil exposed to the sun. The death of the eggs seems to be due to heat since the temperature of the soil was found to go above that known to be lethal to them. In some field experiments in Virginia (Otto, 1929) it was also found that ascaris eggs did not survive on soil composed mostly of cinders when exposed to the sun although some survived on unshaded sandy spots. Here, too, high temperatures seemed to be the lethal factor. It seems probable, therefore, that the killing of the eggs on certain types of soil by the heat of the sun's rays is an important factor especially in the tropics in limiting the spread of ascaris. The point must be kept in mind also that while ascaris eggs are more resistant to desiccation than those of trichuris or than the larval stages of the hookworm, they are soon

* A recent review of the most important literature on the temperature, moisture and chemical relations of the eggs of the human ascaris is given by Otto (1929).

killed if subjected to too much drying. Otto (1929) found that ascaris eggs on glass slides were all dead in about nine days in an atmosphere 40 to 50 per cent saturated with moisture and that on the surface of dry soil in the open room all the eggs were dead in less than a month. Caldwell and Caldwell (1928) came to the conclusion from experiments with ascaris eggs on different types of soil that desiccation was the most important lethal factor. It seems evident, therefore, that the dryer the climate of any region the greater the destruction of the eggs. This is apparently often compensated for by the enormous egg production, because ascaris infestation is very often found in regions of rather low rainfall.

Some recent field experiments in Panama are of interest (Cort, Schapiro, Riley and Stoll, 1929) in this same connection since they suggest considerable fluctuation in the level of ascaris infestation between the wet and the dry seasons. Examinations by the egg counting method were made of the people of a small unsanitated village at the beginning, the middle and the end of the rainy season. In this series the egg counts made at the end of the rainy season were about twice the size of those made six months earlier. Another study in the same region of two other villages (Cort, Schapiro and Stoll, 1929) showed the same thing. The increase in egg counts was particularly evident in the worst ascaris families, where the conditions were evidently particularly favorable for the spread of this parasite. This was interpreted to mean that there is a considerable fluctuation in the yearly level of ascaris infestation in regions with a long dry season, produced by a constant rapid loss of worms and conditions less favorable for reinfection during the dry season. Although at present there is no definite evidence available, there is every reason to believe that the ascaris burden is reduced by the long cold winter of the mountain sections of the southeastern United States and that the peak of the yearly cycle comes late in the fall. In fact this suggestion is very definitely put forward by Otto (1930) in a paper in which he summarizes the evidence for a constant fluctuation of ascaris infestations due to loss of worms and reinfection.

Except for a more rapid destruction of ascaris eggs in sandy soils and in those made up of cinders by the heat of the sun's rays, there is at present no evidence that the type of soil is a determining factor in the spread of ascaris. This is of particular interest in the United States because the suggestion has often been made that the peculiar distribution of this parasite is in some way related to the character of the top soil. The important endemic centers of ascariasis of any size in the United States are located in the mountainous sections of the southeastern part chiefly in West Virginia, Virginia, Kentucky and Tennessee. Other areas where rural sanitation is equally primitive and where in many

cases hookworm disease is endemic, as for example in southern Alabama and Georgia, are practically free from human ascaris. It has been impossible to demonstrate any constant soil differences between these ascaris and non ascaris regions, or any differences in general environmental factors that could possibly explain this situation. In fact there appears to be no similar predilection of human ascaris for mountain regions in any other part of the world. It is also of interest that Caldwell and Caldwell (1926) have shown that while *Ascaris lumbricoides* is practically unknown in southern Alabama in man it is common in the pig. These authors make use of this difference in distribution as a rather convincing argument that the ascaris of man and of the pig are not identical. The prevalence of the pig ascaris in this region also argues against the operation of soil or climatic factors in keeping down human ascaris. It becomes almost necessary in light of all the available evidence to fall back on differences in human habits to explain the differences in ascaris infestation in different parts of the southern United States.

Recent studies in the lowlands of western Tennessee have given some evidence along this line (Otto, Cort and Keller, 1931). In spite of the general very low incidence of ascaris in this region a small proportion of typical ascaris families were found. These families showed the usual conditions of soil pollution associated with heavy infestations with the stools concentrated near the houses. Many of the negative and lightly infested families were also without any sanitation. In such families almost invariably stools were deposited at a distance from the houses often in barns or chicken houses. It was suggested that the keeping of pollution at a distance from the dooryards was an important factor in keeping down the infestation in this region. Certainly the association of heavy worm burdens with dooryard pollution becomes more and more evident with each series of field studies that has been made. It was further suggested that the flatness of the country made it easier and more necessary for the sake of protection for the people to defecate further from the houses. That this difference in soil pollution habits is really the determining factor in the low incidence of ascaris in the plains areas of the southern United States has not been demonstrated, but it is as yet the only clue that has been found.

EFFECT OF TREATMENT ON ASCARIS INFESTATION IN POPULATION GROUPS

In addition to information on the factors influencing the spread of ascaris the recent epidemiologic studies have also given data on the effect of treatment and sanitation in the control of this parasite. Two drugs, santonin and oil of chenopodium, have been widely used as anthelmintics for human ascaris. The evidence available recently dis-

cussed by Hall and Augustine (1929) demonstrates very clearly that oil of chenopodium is by far the more effective of the two drugs. Recently it has been shown both by laboratory and field tests by Lamson and his associates that hexylresorcinol is also a very effective and safe drug for treatment of ascaris (Lamson, Ward and Brown, 1930; Brown, 1930). Since this drug seems to be less toxic to the patient than oil of chenopodium it may well become the drug of choice.

What is of particular interest in this connection, however, is the considerable body of evidence available from egg count studies which shows that treatment is not effective in the control of ascaris in population groups. In field experiments in Panama it was found that no effect of treatments with oil of chenopodium given at the beginning of the rainy season could be demonstrated by egg counts made six or seven months later (Cort, Schapiro and Stoll, 1929). In a group of children the treatment had reduced the egg count by over 90 per cent. Seven months later reinfection had raised the egg count of this group to one and one half times the pre-treatment level. More recently a study of reinfection after treatment has been made in southwestern Virginia (Otto, 1930). Egg counts of 157 individuals of all ages in the same community were made in the spring and summer of 1928 and treatments were given to those found positive for ascaris. Reexamination of 98 individuals of this series showed that the egg counts had been reduced by about two-thirds. The reexamination of these same people the following spring showed that in less than a year the egg count of the group had returned to the pre-treatment level. In both these studies, of course, the treatments were only partially effective and the soil was heavily seeded with eggs so that conditions for reinfection were favorable. It seems probable, however, that even if 100 per cent of the worms in groups of this type were eliminated by treatment reinfection would be rapid on account of the numbers and longevity of the eggs found in the yards of heavily infested families. Perhaps treatments might be of more lasting value if given during a dry season or winter when the dangers of reinfection appear to be considerably reduced. At any rate the evidence available suggests that mass treatment is not an effective control measure for ascaris and that the expenditure of money by health authorities for this purpose is to say the least a doubtful procedure. Of course treatment in any ascaris population remains as a very important curative measure for relieving the heavily infested individuals especially the young children of dangerous worm burdens.

SANITATION IN ASCARIS CONTROL

The field investigations of the last few years have brought out some rather startling facts on the relation of sanitation to ascaris control. In

the Panama studies it was found that the sanitary campaign that has been carried out there for hookworm control, had apparently not been effective in reducing the ascaris burden. In fact in the two groups with the highest average ascaris infestations of the whole Panama series a great deal of sanitary work had been done and the majority of the families had privies, which were used by at least some of the members. The general conclusion was drawn that in the areas studied in Panama the development of household sanitation, which was shown to be definitely reducing the hookworm, had not appreciably limited the spread of ascaris. The explanation advanced for this situation was that ascaris was chiefly spread by the young children and that they were not using the privies.

The field investigations in Virginia, Tennessee and Kentucky have revealed the same situation. All through these regions many families were found with well kept constantly used privies in which ascaris is kept up by soil pollution near the houses by the youngest children. For example in the 329 families especially studied in the mountain sections of Tennessee (Otto, Cort and Keller, 1931) more than half (104) of the 194 having heavy ascaris infestation had privies, which in almost all cases were found to be in use. It seems evident, therefore, that both in the United States and in Tropical America the extensive sanitary campaigns that are being carried on are in many cases failing in bringing ascaris under control.

These findings do not of course demonstrate that there has been no reduction of ascaris due to the sanitary work. In the endemic areas in the United States there is a great deal of evidence of constant improvement, and the same thing must also be true wherever campaigns have been carried out over considerable periods of time. Conditions in the United States will be used to illustrate these points. It is clear in the first place that there has been an improvement in living conditions and a reduction or elimination of infestation in the large number of people that have moved in from the rural districts to the towns and cities. In practically every community visited in these regions there were numbers of families that had developed household sanitation to the point where they were wholly or almost wholly free from ascarids. Sometimes such families were on the same economic level and lived close to those heavily infested. Further there are areas of considerable size in the general mountain sections, where ascaris is endemic, where intensive sanitary work combined with other factors that have raised the general cultural and economic level of the population has practically eliminated ascaris. Such areas in some cases include whole counties where there have been full time county health departments over a considerable period of time, and where the people have made economic advance and have lost their isolation.

It is of interest in this connection that fecal examinations for ascaris can often be used to check the effectiveness of sanitary work. Such examinations made at intervals after the introduction of privies into a community infested with ascaris will give a pretty good index of the extent of soil pollution remaining and will indicate the families needing further attention. In such a community ascaris infestation might be called an index of the status of household sanitation.

It is evident from the discussion given above that the control of ascaris in any area is a matter of considerable difficulty, and that to be effective a control program must take into consideration the actual situation in the particular community involved. It seems perfectly clear, therefore, that time and money spent in careful preliminary investigations by properly trained individuals will in most cases at least be well spent. Since, after all, ascaris is only abundant among those people who fail to observe the simplest rules of household sanitation and personal hygiene, anything that will tend to raise the general economic and cultural level will reduce its prevalence. One of the first steps in improving the general sanitary condition of an area is the development of an organized health department. In fact it is generally recognized in those parts of the United States where intestinal helminths are still common, that the most progress is being made in counties that have a full time county health officer with a well organized department. In other words improvement in household sanitation, which will produce a reduction in the prevalence of ascaris, goes hand in hand with the development of the general public health program.

There are, however, a few simple suggestions for ascaris control in the United States that might be made in light of the recent epidemiologic studies recorded above. In the first place it is obvious that the critical thing in the control of ascariasis is not the mere introduction of privies into unsanitated areas but their conservation, replacement and constant use especially by the children of preschool and early school age. Certain very practical points seem in many places to have been entirely overlooked. First the privy should be placed near enough to the house so that it can be readily reached by the children both in winter and summer and in the second place it should be mechanically adapted for children's use. It is surprising that almost invariably the seats in the privies built in the rural districts where ascaris is prevalent are designed only for adults and are difficult and even dangerous for children to use. The correcting of this situation is certainly a necessary preliminary step in any program for eliminating soil pollution by children. Beyond this, progress will have to depend chiefly on education in proper methods of living. Intensive instruction in the home especially by the sanitary inspector and public health nurse seems to be the most promising method

of approach. This should be supplemented by more practical instruction in the rural schools in these regions in personal hygiene and household sanitation. Such courses given in the early grades should stress the dangers of soil pollution in the spread of disease, and should certainly take up the simple methods of excreta disposal that are adapted to rural homes. These are often the subjects, which the teacher, usually from an entirely different environment and city trained, is least desirous of discussing. It is here that the cooperation of the health officer and his staff is most valuable in giving the teacher the necessary information or in giving the instruction themselves. It happens that in the United States the ascaris problem is a part of the general economic and social problems of the "poor mountain whites" of the southeastern Appalachian range. Certainly the raising of the standards of household sanitation and personal hygiene among these people to the point where ascariasis ceases to be important must be one of the early steps in their general advancement. Finally with ascaris so widely prevalent in both urban and rural communities in such extensive areas of the world and so clearly an index of the status of sanitation, it seems evident that a much larger part of the program for improved sanitary conditions might well center in campaigns for its control.

SUMMARY

In the last five years important advances have been made in our knowledge of human ascaris by intensive field investigations which involved fecal examinations by the dilution egg counting method, examination of soil samples to determine the distribution of ascaris eggs in infested communities, and careful inspections and studies of soil pollution habits. A description of the use of these methods in studying a population group is given in some detail. Studies made by these methods in Panama and the southern United States have shown that soil pollution near the houses especially by the youngest children is a very important source of infection. Infection would be brought about under such conditions by the tracking of the eggs into the houses and by hand to mouth infection of children playing in dirt containing embryonated eggs. Where human excrement is used to fertilize the crops as in certain oriental countries ascaris is very prevalent in the whole population. The eating of raw or partially cooked vegetables to which ascaris eggs adhere seems under these circumstances to be an important source of infection.

The dilution egg counting method has been found to be a useful and valid quantitative measure of ascaris infestation in population groups. From the limited number of egg count studies of the last few years certain additions to our knowledge have been made on the distribution

of this parasite and on the factors influencing its dissemination. In the first place it has been found that the family is almost always the unit of dissemination, so that most of the studies must center on the environment of this group. An analysis of the negative cases in the groups egg counted in Panama and the United States has suggested that above about 20 to 25 per cent the negatives come almost entirely from the negative or lightly infested families. In groups constantly exposed to infection, as in series of ascaris families, a large proportion of the negatives are in adults with habits that do not bring them in contact to such an extent as the children with the sources of infection. The small proportion of negatives in children exposed constantly to infection appears to be composed of cases from which the worms have been spontaneously expelled. Another remarkable thing about ascaris infestation is the concentration of about 50 per cent of the worm burden in any group in about 5 per cent of the individuals. This suggests that rather extreme conditions are necessary to build up heavy infestations.

An age and sex distribution in which the children are much more heavily infested than the adults and in which the young adult females have much higher counts than the males is characteristic of the series of examinations made in Panama and the southeastern United States. This distribution appears to be associated with sources of infection produced principally by the soil pollution of young children near the houses. In the Orient where the situation is complicated by the use of human excrement as fertilizer the adults have a much more general and heavy worm burden. This situation and the finding in the series of egg counts from China of groups of adults with average egg counts comparable to some of the most heavily infested children, indicates that when adults are sufficiently exposed to infection, they show no marked lack of susceptibility.

While the presence of a heavy ascaris worm burden is usually associated with poverty, people of the lowest type have been found in regions where this parasite is endemic with practically no infestation, due to absence of soil pollution or to the habit of depositing the stools at a distance from the houses. On the other hand in many cases the best families in ascaris regions are infested on account of the careless habits of the younger children. Ascaris is not to the same extent as the hookworm a rural problem since the crowded conditions of poorly sanitated cities especially in tropical or subtropical countries are very favorable for its spread.

On account of the remarkable resistance of the eggs of ascaris to adverse conditions and their ability to develop under a very wide range of conditions this helminth is probably the most prevalent and widely distributed of all the human parasites, being found both in cold regions

and those with a low rainfall. It is often found abundantly in places where there is too little moisture for the development of the eggs of trichuris. Drying, however, seems to be one of the most important factors in killing ascaris eggs. The eggs are also killed especially in the tropics by the high temperatures produced by the direct rays of the sun on sand and certain other types of soil. There is some evidence that the level of ascaris infestation is considerably reduced during a long dry season by the rapid loss of worms over a period of reduced reinfection. It seems probable that a similar fluctuation occurs in those areas with a long cold winter. The type of soil does not seem to be a limiting factor on ascaris spread. In fact except under extreme conditions the intensity of infestation in any area appears to be determined chiefly by human habits and not by general environmental conditions.

Recent field studies have emphasized the rapid reinfection with this parasite after treatment. For this reason treatment of a population group cannot be considered as an effective control measure. On the other hand the effectiveness of oil of chenopodium and hexylresorcinol as ascaricides makes it easy to relieve heavily infested individuals especially young children of dangerous worm burdens.

In many places ascaris infestation has been reduced or eliminated by sanitary programs carried out over long periods of time, especially where other factors have raised the social and economic level of the population. It has been shown, however, that very frequently sanitary work has not been successful in controlling this parasite because of the failure of young children to use the facilities provided. For ascaris control, therefore, it is necessary to provide facilities well adapted for children's use and to concentrate the educational program on the prevention of soil pollution by young children. Since the presence of this parasite in both cities and rural communities over such wide areas of the world can be used as an index of the status of sanitation it seems that campaigns for its control might form a larger part than at present of programs for the improvement of sanitary conditions.

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ADDENDUM

Since this address was delivered at Cleveland there has appeared a paper to which I desire to direct attention. It is by P. D. Lamson, E. L. Caldwell, H. W. Brown and C. B. Ward, 1931, on Hexylresoreinol in the Treatment of Human Ascariasis, and is printed in the American Journal of Hygiene, 13:568-575 (1931).

STUDIES ON CREPIDOSTOMUM. I. *CREPIDOSTOMUM ISOSTOMUM* N. SP.*

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During the past two years about 90 per cent of the pirate perch, *Aphredoderus sayanus* (Gilliams) caught in East Lake Fork, a drainage ditch in Champaign County, Illinois, have been found to be infected by a small species of Crepidostomum. This trematode is described below as *Crepidostomum isostomum* n. sp. Thus far it has been found only in the pirate perch, and when present is always in either the intestine or the pyloric ceca. The number of specimens in each host ranges from one to forty. Several hundred individuals have been collected in the course of this investigation; specimens have been studied in the living condition as well as in toto mounts and in serial sections.

Mature specimens of *C. isostomum* are usually from 0.8 to 2.0 mm. in length; none of my mounted specimens exceeds 2 mm., but it is possible that larger specimens will be found in future collections. Living individuals extend beyond 2 mm. at times. The part of the body anterior to the acetabulum is narrower, thinner dorso-ventrally, and much more mobile than the part posterior to the acetabulum. The pre-acetabular portion in living animals may be extended so far that its length equals or even exceeds the post-acetabular length, and at other times it may be contracted so much that the oral sucker is pressed hard against the acetabulum. Typically the body begins to widen at the acetabulum and reaches its greatest breadth in the region of the testes. More rarely the maximum breadth occurs at the level of the ovary. Many preserved specimens have identations in the lateral margins opposite the acetabulum, marking off the mobile anterior region from the post-acetabular portion of the body. The maximum breadth varies between one-third and one-fifth of the body length, but usually it is approximately one-fourth. The post-acetabular region is considerably flattened dorso-ventrally, the depth being about one-third of the breadth.

The anterior extremity of the worm is crowned with six conspicuous, highly mobile lobes or papillae. Four of these oral papillae are dorsal to the oral sucker and of approximately equal size, while the other pair are ventral and lateral, and usually noticeably larger. The two pairs of dorsal papillae are rounded at the distal ends and somewhat flattened dorso-ventrally; in some specimens the median pair is definitely

* Contribution from the Zoological Laboratory of the University of Illinois, under the direction of Henry B. Ward, No. 399.

anterior to the lateral pair, while in other cases the bases of all four papillae are on the same line. The ventral papillae, which are also flattened, and rounded at the ends, are often turned up on edge so that the flat sides are directed to the front and rear; in this position they seem to be sharply pointed at the ends when the worm is viewed from the dorsal or ventral sides. Oral papillae are not only variable in size in different individuals, but are also variable in each individual, being extended, contracted, straightened out or bent in different directions as the worm moves. Therefore it is not safe to place much reliance on differences in the oral papillae as characters for the differentiation of species, at least in the case of the genus Crepidostomum. However, it is safe to say that the papillae of *C. isostomum* are much more conspicuous than those of any other Crepidostomum except *C. cornutum*, being larger in proportion to the size of the body as well as greater in absolute size; they reach a length of 0.1 mm. in a moderate state of expansion. They also extend farther beyond the margins of the body laterally and anteriorly than do the papillae of any other species except *C. cornutum*. As in other species of Crepidostomum, a thin membrane continuous with the external cuticula of the body extends over the oral papillae; this membrane sometimes encases the papillae tightly like a glove and sometimes covers them loosely like a mitt.

The two suckers are approximately equal in size. The ventral sucker averages a trifle the larger, but in about one-third of the specimens the oral sucker is the larger, and in the majority the suckers are of practically the same dimensions. Both are spherical, as a rule, but the oral sucker is sometimes longer than wide. The orifice of the ventral sucker is usually circular but occasionally transversely elliptical. The orifice of the oral sucker varies considerably, being either roughly circular, somewhat squared, or elliptical with the long axis in the longitudinal plane of the body.

From the oral sucker a short prepharynx, difficult to see in whole mounts, leads into a large pharynx which is sometimes almost spherical but is usually noticeably longer than wide. The length of the pharynx varies between one-half and two-thirds the diameter of the oral sucker. Following the pharynx is an esophagus which is always longer and may be more than three times as long as the pharynx, but is much curved or even convoluted in contracted specimens. The forking of the intestine occurs at the anterior margin of the acetabulum, or more frequently behind the anterior margin and dorsal to the acetabulum. The crura run back over the acetabulum and extend to a point about two-thirds the distance from the posterior end of the posterior testis to the posterior extremity of the worm. The entire intestine is smooth and thin-walled, while the esophagus is comparatively thick-walled but stains more lightly.

The genital pore is ventral, approximately median, and definitely anterior to the crural fork. It varies in position from the posterior end of the pharynx to the anterior margin of the acetabulum, but is usually about half-way between these limits when the worm is at rest. The male and female ducts open through a common external orifice.

The cirrus pouch is broad, roughly ovoid, and sometimes bent or folded upon itself (Fig. 1). It reaches back dorsal to the acetabulum as far as the center of the latter. In some cases the cirrus pouch is entirely anterior to the acetabulum. In only two cases has it been found to extend posteriorly beyond the center, and in none as far as the posterior margin of the acetabulum.

The ovary is close to the dorsal surface, and is dorsal to the posterior edge of the acetabulum or slightly posterior to it. It is usually almost spherical, but is often flattened somewhat by being pressed against the ventral sucker. It may be either median or slightly lateral to the median line on either the right or the left side. The ovary is always smaller than the testes, and often less than half as large, but there is no constant ratio between them.

The testes are very variable in size, shape, and position. They always lie within the posterior half of the body, some distance back of the ovary, and are usually somewhat oblique in relation to the median line of the body, but are occasionally tandem in the median line. In size the testes vary from less than half the size of the suckers in immature specimens to dimensions which exceed the suckers in the largest specimens, but this increase in size of the testes has no exact relation to the growth of the body. In some cases the testes are almost spherical, but usually they are somewhat irregular in shape due to the pressure of other structures, especially the anterior testis which is often distorted by the pressure of the uterus and eggs. In specimens in an average state of contraction the testes have a dorsoventral or vertical diameter about equal to the horizontal diameters, but in unusually contracted specimens the dorso-ventral diameter or depth greatly exceeds the antero-posterior diameter or length. The cause of some variations in the shape and position of the testes can be seen by watching a living worm as it extends and contracts. At the limit of contraction the testes are flattened against each other, become twice as wide as long, and are oblique in relation to the median line of the body; at the extreme of extension the testes are drawn some distance apart, become twice as long as wide, and are tandem in the median line.

The seminal receptacle is immediately posterior to the ovary and close behind it is the large vitelline reservoir. Both of these organs are in the dorsal half of the body. Laurer's canal is well-developed. The uterus, which is very thin-walled and stains lightly, is difficult to trace; it seems to make only one or two loops and is always confined

to the space between the acetabulum and the anterior testis, except for the distal part which runs over the acetabulum toward the genital pore. The eggs are exceptionally large, averaging over 80μ in length, but are few in number; no specimen in my possession contains more than twenty eggs. The egg-shell is almost colorless, being very lightly tinged with yellow.

The vitellaria extend along the lateral margins of the body from the genital pore almost to the posterior end of the worm; they are almost entirely confined to the space between the intestinal crura and the body edge, but a few follicles lie in the intercrural space between the ovary and the anterior testis and between the two testes, and a row of follicles extends along the median side of each branch of the intestine from the posterior testis to the ends of the crura. Nowhere do the vitellaria of the two sides meet or extend inward as far as the median line as they do in *Crepidostomum laureatum*. The follicles are practically colorless in life but yellowish in alcohol specimens, and are irregular in shape. With the exception of a very few follicles the vitellaria lie close to the ventral surface of the body.

The excretory bladder is an elongated bottle-shaped sac lying close to the dorsal surface and opening to the outside through a narrow neck of somewhat conical shape. The pore is either terminal or slightly dorsal. The shape of the bladder changes considerably as the worm moves and is always somewhat irregular due to the pressure of neighboring organs, particularly the testes. The bladder extends forward at least as far as the anterior edge of the anterior testis, and frequently as far as the posterior edge of the ovary; in general the anterior end seems to coincide with the position of the seminal receptacle. On each side of the body an excretory tube from the anterior end of the worm runs along near the lateral margin of the body, meets a similar tube from the posterior end near the acetabulum, and the two join to form a common tube, much convoluted, which runs back and inward to empty into the anterior end of the bladder. The positions of the finer tubules and flame cells have not yet been worked out. In live specimens the bladder is full of excretory granules or droplets with a high index of refraction, appearing almost black by transmitted light and white by reflected light, but these excretory products disappear in the process of killing and preserving.

A pair of conspicuous eyespots lie lateral to the pharynx or slightly posterior to it. They are not on either surface but are deep in the body, about the same distance from both surfaces. As a rule the eyespots are more conspicuous in the smaller specimens, but they are unmistakably present even in the largest; in fact, the largest specimen in my possession has very large and distinct eyespots. These eyespots are composed of groups of small dark brown pigment granules which usually look black

when a mounted worm is examined under the microscope; sometimes these pigment granules are gathered in a compact group, forming a distinct spherical eyespot, and in other cases they are more or less scattered, forming a diffuse cluster. Many specimens have one eyespot scattered and the other compact.

A brief specific diagnosis may be stated as follows:

Crepidostomum isostomum HOPKINS 1931

Length of mature specimens about 0.8 mm. to 2.0 mm. Breadth 0.25 mm. to 0.6 mm., usually about one-fourth length. Body narrows, necklike, anterior to acetabulum, widens posterior to acetabulum, reaching greatest breadth usually in region of testes. Oral papillae six, conspicuous, reaching length of 100μ or more; of these four are dorsal and equal, two are ventral, slightly larger, and projecting laterally; all are bluntly rounded at tip and none are notched. Eyespots conspicuous, persisting throughout life, but somewhat scattered in some mature specimens; situated one on each side of pharynx or just posterior to pharynx. Suckers equal; average diameter about one-ninth length of body, both suckers averaging about 0.165 mm.; usually spherical or nearly so; apertures never slitlike. Ventral sucker one-third to one-half of body length from anterior end. Pharynx barrel-shaped, 80 to 100μ long. Prepharynx present but difficult to see in preserved specimens. Esophagus two to four times as long as pharynx. Forking of intestine from anterior margin to center of ventral sucker, entire intestine close to dorsal surface, crura running nearly to posterior end of body. Testes large, irregularly spherical, usually slightly oblique. Ovary usually spherical, smaller than testes, dorsal to posterior margin of ventral sucker, usually lateral but sometimes median. Cirrus pouch large, ovoid, reaches back only to center of acetabulum; cirrus much convoluted. Genital pore median, ventral, anterior to forking of intestine, usually about half-way between pharynx and ventral sucker. Vitellaria outside of intestinal crura from genital pore almost to posterior end, and also along median sides of crura behind testes, between testes, and between ovary and testes; only a few follicles are dorsal to intestine Excretory bladder bottle-shaped, dorsal, reaches anteriorly as far as seminal receptacle. Eggs 1-20 in number, 70-90μ in length, 40-60μ wide; average length about 83μ.

Type specimen in collection of Professor Henry B. Ward, No. 30.53.

Investigation of the life history of this species is now in progress. The metacercariae have been found encysted in mayfly nymphs, and immature eye-spotted stylet cercariae probably belonging to *C. isostomum* have been found in *Sphaerium* sp. Scarcity of material caused by the drying up of streams prevented any further work during the summer

of 1930, but it is hoped that conditions will permit experimental work and the completion of research on the life history during the coming summer.

Thanks are due to Professor Henry B. Ward for many valuable suggestions and for the use of material from his collection and library which has made this study possible.

Explanation of Plate XIV

All drawings made with aid of camera lucida. Scale line represents 0.2 mm. in all figures except Fig. 5, where it represents 0.05 mm. Fig. 9 was drawn from a living specimen, all others from fixed and stained specimens.

Abbreviations Used

b, anterior end of excretory bladder; *c*, cirrus pouch; *e*, egg; *f*, forking of intestine; *s*, seminal receptacle; *sv*, seminal vesicle; *v*, vitelline reservoir.

Fig. 1.—Type specimen of *Crepidostomum isostomum*, toto mount, dorsal view.

Fig. 2.—Young specimen bearing only one egg, dorsal view; killed under cover glass in somewhat flattened condition; toto mount.

Fig. 3.—Sagittal section of a mature specimen through the mouth and genital pore.

Fig. 4.—Same specimen as Fig. 3, sectioned through ovary and seminal receptacle

Fig. 5.—Longitudinal section through mature egg.

Fig. 6.—Immature specimen, showing arrangement of papillae; toto mount, ventral view.

Fig. 7.—Same as Fig. 6, dorsal view.

Fig. 8.—Smallest specimen found in pirate perch; toto mount, laterial view.

Fig. 9.—Encysted metacercaria from nymph of mayfly, *Ephoron* sp.

Fig. 10.—Metacercaria from nymph of *Ephoron* sp, pressed out of cyst and considerably flattened under cover glass when killed; toto mount, ventral view. Scale line applies to both 9 and 10.

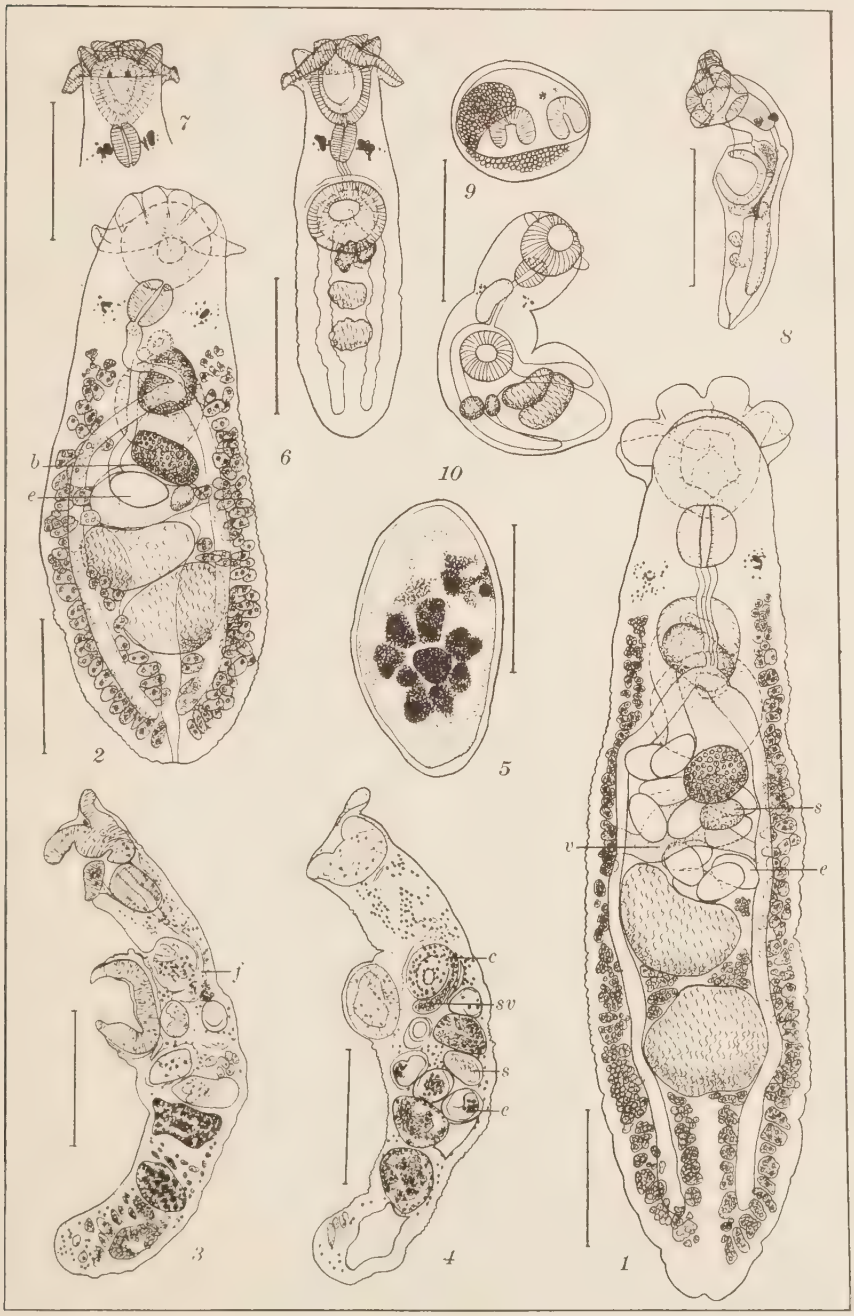

PLATE XIV

EXPERIMENTAL INFESTATION OF WHITE RATS WITH *HEPATICOLA HEPATICA**

Doys Andrew Shorb

The finding of the rat parasite *Hepaticola hepatica* (Bancroft, 1893) Hall, 1916, in abundance in the wild rats of Baltimore presented an opportunity for studying the natural methods of infection with this parasite. Seventy-one wild rats of the species *Epimys rattus norvegicus* were used as the source of infective material. These wild rats were captured in and around Baltimore in the spring of 1930 and the livers were examined for the characteristic yellowish-white lesions caused by *Hepaticola hepatica*. If lesions were found, portions of the yellowish-white part were removed, teased apart, and examined with the low power of the microscope for eggs. By this method it was determined that thirty-four rats of 47.9 per cent were infected with *H. hepatica*.

The livers of the thirty-four rats infected with *H. hepatica* were fed to six laboratory-bred rats. These and the rats used in the subsequent experiments in this paper were of a strain which has never harbored *H. hepatica*, this having been determined by repeated examinations of the livers of other rats from the laboratory stock both before and since these experiments were begun. Part of the infected area of each liver was not fed to the experimental rats but was kept for control on egg development. The feces of these six rats were collected for three consecutive days. They were found to contain eggs of *H. hepatica* in the same stage of development as in the livers which had been fed to the rats. These eggs were separated from the feces. The method of recovering the eggs was a modification by McCoy (1929 a and b), of that used by Lane (1922) in his direct centrifugal flotation method of fecal diagnosis. These six rats were killed and examined six weeks later and all were found to be negative for *H. hepatica*.

The eggs recovered from the feces of the six rats were separated into three portions. These were placed in petri dishes and were incubated at 22°, 30°, 37.5° C., respectively. At the time they were placed in the incubator they were still in the same stage of development as when in the liver, i. e., in the one to four cell stage. Examinations of the eggs were made on the twenty-fifth day and also on the forty-second day of incubation. On the twenty-fifth day development was as follows: In the 22° incubator, appeared one cell to late morula stages; in the 30°

* From the Department of Helminthology, School of Hygiene and Public Health, Johns Hopkins University. The writer wishes to thank Dr. W. W. Cort for many helpful criticisms and suggestions.

incubator there were a few vermiform and late morula stages, and in the 37.5° incubator nearly all eggs were embryonated and the rest degenerated. By the forty-second day the following stages had been reached: At 22° a few morula, many tadpoles, and some vermiform embryos were seen; at 30° nearly all eggs contained active embryos; and at 37.5° most of the eggs were degenerated.

The pieces of diseased liver containing the eggs of *H. hepatica* which had been saved for control on egg development, after having been chopped into small pieces, were also divided into three parts and incubated at 22°, 30°, 37.5° C., respectively. This was done on the same day that the livers, in which the rest of the eggs were found, were fed to the rats. As has been previously stated all the eggs were in the one to four cell stage. In twenty-five days little or no change was apparent in these eggs in the 22° or 30° incubator. In the 37.5° incubator a few were in the early morula stage. On the forty-second day there were a few morula stages in the 22° incubator and many in the 30° incubator. Most of the eggs in the 37.5° incubator had degenerated while the rest were, for the most part, in the morula stage. It is seen that development of these eggs is much slower than of those that had passed through the rats.

Those eggs from the lot which had passed through the rats, which had been incubated at 30°, were left for two weeks longer at the same temperature to make certain that they were infective. By means of a syringe and a stomach tube they were fed to fifteen white rats, and at varying intervals, after two weeks, these rats were killed and examined. Young forms of *H. hepatica* were found after two weeks of infection. Both mature worms and eggs were found after one month. All the rats were found to be infected.

Finally, a liver from one of the experimentally infected rats, killed thirty-five days after infection, was fed to a cat. The feces of the cat were collected for three days and the eggs were separated by direct centrifugal flotation. These eggs were incubated at 30° C. and many were embryonated at the end of thirty days.

Laboratory infection of rats was demonstrated by Bancroft (1893), Nishigori (1925), and others. These infection experiments were done with eggs taken directly from infected livers. They were incubated to embryonation and other rats were easily infected with these embryonated eggs. This, however, does not explain how infections occur naturally. Two theories of the method of infection of *H. hepatica* have been advanced by different authors. The first is, that the eggs pass from the liver, down the bile duct, and out with the feces; then become embryonated and infective when eaten by the proper host. Raillet (1898) found eggs in the feces of a rat infected with *H. hepatica*,

but Nishigori (1925) was able to find only one egg after a long search. Bancroft (1893) was unable to find any. This would indicate that, as a usual thing, eggs probably do not pass out with the feces. It is also possible that eggs never come down the bile duct and pass out with the feces, and the eggs found by Raillet and Nishigori may be accounted for in some other way, such as having come from infected food material. It would appear that this is not the usual method of propagation.

The second theory is that a susceptible host is infected by consuming liver containing infective Hepaticola eggs. There is no experimental evidence to support this theory. It is untenable for the following reasons: (1) The eggs do not develop in the liver, and (2) the eggs do not have time to embryonate in the intestine of the animal eating the liver, but pass through the intestine unchanged and uninjured.

Because of the inadequacy of these theories the following explanation is offered on the basis of the experiments outlined above: In nature, a susceptible animal becomes infected with *H. hepatica* by ingesting eggs that have been freed from infected livers and then become embryonated.* These eggs are released from the livers in two ways: by decaying of the animal or by its being eaten by another animal. In the first instance, where the eggs have not been freed by passage through an animal, they develop very slowly. Raillet (1898) found segmentations of eggs in liver kept four months, and embryos in five to six months. Bancroft (1893) found embryos in five months. This agrees with the experimental data given above. A process somewhat similar to the experiments of Raillet and Bancroft would take place in nature if an infected animal died and were allowed to decay without being eaten by another animal, under which conditions the eggs would become embryonated after five or six months in a favorable environment.

Not only are rats scavengers and notoriously cannibalistic, but they are also prey for cats, dogs, owls and other carnivorous animals. Therefore, a natural process of decay as described above would be exceptional. Even though Hepaticola eggs were freed thus, the temperate zone, with its short summers, would not allow sufficient time for development. Moreover, the food habits of rats, and the fact that they are prey to so many animals makes ample provision for the freeing of the eggs of *H. hepatica* by passage through the digestive tract of animals feeding on infected hosts. It has been seen that eggs freed in this manner, develop rapidly and, in the summer temperature common in the temperate zone, the eggs would be embryonated in about a month.

* After these experiments were completed the author received a reprint of a paper on Hepaticoliasis by Troisier and Deschiens (1930) in which this same explanation is advanced. These authors, however, have carried out no experiments to demonstrate their view.

Although only rats and a cat were used in this experiment to free the eggs, other carnivorous mammals or birds and reptiles might also be as efficient.

SUMMARY

Of seventy-one wild rats obtained in and around Baltimore, 47.9 per cent were infected with *H. hepatica*. Six white rats fed on the infected livers of these wild rats did not develop the infestation, but the eggs passed through the intestine unchanged. These eggs were recovered from the feces and became embryonated in twenty-five to forty-two days at 30° C. Fifteen white rats became infected when fed on these embryonated eggs, while eggs in pieces of the rats' livers but not passed through an animal, were developed only to the early morula stage in forty-two days. Eggs from infected livers fed to a cat also developed vermiform embryos in thirty days.

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NEMATODES FROM FLYING LEMURS IN THE PHILIPPINE ISLANDS AND FROM BIRDS IN CHINA*

H. J. Chu

The parasitic worms in the Philippine Islands have been studied chiefly from ruminants, horses and hogs (Schwartz, 1925), but as far as one can see from the literature nematodes from flying lemurs have not been examined. I had an opportunity to secure specimens from four flying lemurs collected by Mr. F. S. Manipol, School of Hygiene and Public Health, University of the Philippines, December 17, 1929. A careful study of these parasites showed the necessity of placing them in a new genus of Oxyurinae. The present paper further contains descriptions of four species of nematodes from birds in China. These specimens were collected by Dr. E. C. Faust, then chief of the Division of Parasitology, Peking Union Medical College. All specimens were preserved in formalin and were studied after clearing in glycerine; if glycerine did not clear the worms sufficiently, lactophenol and pure carbolic acid were used.

A description is given of the following six species: *Hocpplius spinosus* and *H. boholi,* n. g., n. sp.; *Physaloptera reevesi,* n. sp.; *Ascaridia geei,* n. sp.; *Diplotriaena manipoli,* n. sp.; and *Serratospiculum chungi* Hoeppli and Hsü, 1929.

Hoepplius nov. gen. [Figs. 1-9]

Generic Diagnosis.—*Oxyurinae:* Mouth circular with six lips on which the female has teeth; head with four submedian papillae and two amphids; vestibule absent. Esophagus with a posterior bulb separated from the rest by a slight constriction. Male with one spicule and caudal alae. Female with two ovaries, eggs asymmetrical, vulva in the anterior region of the body.

Hocpplius spinosus nov. spec.

Hoepplius: Head with four submedian papillae and two amphids. Cuticula has transverse striations along the whole length of the body and bears spines arranged in transverse and longitudinal rows in the anterior region of the body. Male with caudal alae, one pair of pre-anal papillae and one large pedunculated pre-anal papilla. There is a

* Contribution from the Division of Parasitology, Department of Pathology, Peiping Union Medical College, Peiping, China.

single spicule and no gubernaculum. Female with a long, slender tail and two ovaries.

Host: *Cynocephalus volans* Linnaeus.

Location: Large intestine and cecum.

Collected at Bilar, Bohol, Philippine Islands.

Type Specimen: Helminthological Collection, P.U.M.C., Peiping, China. Pei. No. 38.

Male: The body length is 2.96 to 3.87 mm. with an average of 3.37 mm., and breadth of 0.11 to 0.17 mm. with an average of 0.13 mm. The mouth has six lips; the head has four submedian papillae and two amphids. The cuticula has transverse striations and in addition very small spines in the most anterior region of the body. The first two transverse rows of spines are at a very great distance from each other. Between the anterior end and the first striation, the cuticula extends toward each lateral side in such a way that in the frontal view one gets the impression of very short lateral alae. The nerve ring is situated 0.11 mm. distant from the anterior end. The excretory pore could not be seen. The total length of the esophagus is 0.84 mm., ending in a bulb separated by a slight constriction from the rest of the organ. The intestine has no diverticulum. Caudal alae are present supported by three ribs bearing papillae at their ends. There is one spicule, measuring 0.35 mm. in length. A gubernaculum is absent. There are two small pre-anal papillae just in front of the anus and one large pedunculated papilla, 0.14 mm. in front of the anus.

Female: The total length is 8.87 to 10.36 mm. with an average of 9.86 mm. and 0.47 mm. in breadth. The mouth shows the same structure as in the male with the addition that each lip bears a tooth. The cuticula has transverse striations and also spines arranged in transverse and longitudinal rows on the most anterior part of the body, back to about the middle of the esophageal bulb. Around the bulb region these spines are scattered irregularly and become very small and rare. The two first transverse rows are placed as in the male, also in the female, at a great distance from each other. These two rows are very broad and prominent and the spines on them have a characteristic appearance. The nerve ring is 0.25 mm. from the anterior end. The excretory pore could not be seen. The length of the esophagus is 1.96 mm. including the bulb. The vulva is 2.06 mm. behind the anterior end. Around the end of the rectum are four rectal glands. The uterus is rather long ending with two ovaries. The asymmetrical eggs measure 71μ in length and 16μ in breadth. The tail has a slender, pointed end.

Hoepplius boholi nov. spec [Figs. 10-13]

Hoepplius: Head with four submedian papillae and two amphids; mouth with six lips each bearing one tooth in the female. There are

cervical alae; cuticula with transverse striations. Tail slender and pointed. Two ovaries, eggs asymmetrical.

Host: *Cynocephalus volans* Linnaeus.

Location: Large intestine and cecum.

Collected at Bilar, Bohol, Philippine Islands; male unknown.

Type Specimen: Helminthological Collection, P.U.M.C., Peiping, China. Pei. No. 39.

Female: The body length is 9.97 to 10.68 mm. with an average of 10.33 mm.; breadth 0.29-0.37 mm. with average 0.33 mm. The head has four submedian papillae and two amphids. The mouth has six lips each of which bears one tooth. There are cervical alae extending posteriad to the level of the nerve ring. The cuticula has fine transverse striations from the anterior to the posterior end. The excretory pore could not be seen. The esophagus, which has a bulb at the end, measures 2.15 mm. in total length. The vulva is 2.30 mm. from the anterior end. There are two ovaries. The tail is slender and pointed. There are three elongated rectal glands. Eggs, asymmetrical, averaging 71μ in length and 16μ in breadth.

Physaloptera reevesi nov. spec. [Figs. 14-17; 23]

Physaloptera: Male with five pairs of stalked papillae, three pre-anal and two post-anal; three single pre-anal and five paired small sessil post-anal papillae. Spicules equal. Females with two ovaries and two uteri.

Host: *Accipitor nisus.*

Location: Stomach.

Collected at Peiping, China.

Type Specimen: Helminthological Collection, P.U.M.C., Peiping, China. Pe. No. 123a.

The male is 18 mm. long and 1 mm. thick. The mouth has two lips, each bearing three teeth. The head has four submedian papillae and two amphids. The esophagus is differentiated into two parts, the anterior portion of which 0.22 mm. is muscular; the posterior, 1.0 mm. is glandular. The nerve ring is 0.12 mm. from the anterior end. The excretory pore is situated 0.47 mm. from the anterior end. The bursa is lanceolate in shape and the ventral portion has longitudinal rows of tubercles extending from the anterior to the posterior part of the tail. There are five pairs of stalked papillae, of which three are pre-anal and two post-anal. There are three single papillae in front of the anus and two pairs behind. Four pairs of small sessile papillae are located in the posterior part of the tail. The spicules are almost equal, the right measuring 0.295 mm. and the left 0.3 mm.

The length of the female is 27.2 to 28.4 mm., in average 27.6 mm., the breadth 1.8 mm. The anterior part of the esophagus is 0.50 mm. in length and the posterior, 3.48 mm. The nerve ring is 0.43 mm. from the anterior end. The excretory pore is 0.71 mm. from the anterior end. The vulva is in the anterior region of the body between the first and sixth part of the body length. There are two ovaries with two uterine tubes. The eggs measure an average of 50μ and breadth of 30μ.

Ascaridia geei nov. spec. [Figs. 18-19; 24]

Ascaridia: The male has thirteen pairs of caudal papillae arranged at a distance from each other. *A. geei* is related to *A. australis* (Linstow, 1898) Railliet and Henry, 1914, but in *A. australis* the papillae are placed in closely-set rows. The spicules are twice as long as in *A. australis*.

Host: *Turtur orientalis*.

Location: Small intestine.

Collected at Peiping, China.

Type Specimen: Helminthological Collection, P.U.M.C., Peiping, China. Pe. No. 1201a.

Male: The body length measures 36.8 mm. with an average breadth of 2.0 mm. The mouth has three lips. There are four submedian papillae and two amphids. The cuticula has transverse striations but no lateral flanges. The nerve ring is 0.42 mm. from the anterior end. The length of the esophagus is 2.28 mm. The excretory pore could not be seen. The posterior extremity is pointed and has a finger-like projection. The pre-anal sucker is large and has a chitinous rim. There are thirteen pairs of caudal papillae of which nine are pre-anal and four post-anal. Arranged at a distance from each other. The spicules are equal and measure 1.09 mm. in length.

Female: The body length is 42.4 to 47.2 mm. with an average of 45 mm., the breadth is 2 to 3 mm. The exact position of the vulva and excretory pore could not be determined owing to the fact that in all specimens, because of poor fixation, parts of the intestine and uterus had prolapsed in the region of the vagina. The vulva opens approximately 3.05 mm. behind the anterior end. The nerve ring is 0.73 mm. from the anterior end. The esophagus is 2.23 mm. long. The tail is conical in shape. The eggs have an average length of 65μ, and breadth of 40μ.

Diplotriaena manipoli nov. spec. [Figs. 20-22]

Diplotriaena: Mouth without lips; head with four submedian papillae and two amphids. Esophagus clearly differentiated into a short

anterior muscular part and a long, broad, posterior, glandular portion. Cuticula without striation. Caudal papillae absent.

D. manipoli is similar to *D. artemisiana* Schmerling, 1925. The differences are that in *D. artemisiana* there is a transverse striation of the cuticula which is absent in *D. manipoli;* and further that the body and spicules in the two species are different in length.

Host: *Garrulus branchis.*

Location: Body cavity.

Collected at Peiping, China.

Type Specimen: Helminthological Collection, P.U.M.C., Peiping, China. Pe. No. 1151.

The body length in the male is 32 mm., the breadth 0.50 mm. The mouth is simple, without lips. There are four very small papillae and two amphids. The anterior end has two lateral chitinous trident-like processes, typical of the genus, being 85μ long. The body cuticula is smooth and very thin. Owing to it's thinness the muscles are very plainly visible in all cleared specimens. On superficial examination the nuclei of these muscles give somewhat the impression of numerous minute papillae inserted over the cuticula in the anterior and posterior regions of the body respectively. The nerve ring is situated 0.19 mm. behind the anterior end. The esophagus is differentiated into two parts of which the anterior, 0.23 mm. long, is muscular and the posterior, 2.19 mm. in length, is glandular. The tail is rounded without caudal alae and papillae. The spicules are unequal in length, the long one measuring 1.18 mm., the short one, 0.86 mm.

The female measures from 104 to 116 mm., with an average of 111.5 mm. in length and 1 mm. in breadth. The trident is 95μ long. The anterior part of the esophagus is 0.24 mm. long, the posterior, 3.15 mm. The nerve ring is 0.89 mm. from the anterior end. The vulva is 0.67 mm. from the anterior end. The excretory pore could not be seen. The eggs measure from 38 to 40μ with an average of 39μ.

Serratospiculum chungi Hoeppli and Hsü, 1929

In addition to the description of this parasite given by Hoeppli and Hsü, 1929, I can add that by a careful examination of the posterior end of the male worm in ventral view I found two more small post-anal papillae (Fig. 25). In all other respects my specimens resemble the forms described by the previous authors. Their material was collected from *Falco* sp. in the Island of Amoy, Fukien, while I secured two males and three females from *Astur palumborus* in Peiping. In my specimens the body length of the males is longer, and that of the females shorter, than in the specimens from *Falco* sp.

To complete the description of *S. chungi,* I have listed the measurements of my material in comparison with these given by Hoeppli and Hsü.

	In *Astur palumborus*	In *Falco* sp.
Body length—Male	31.0 mm.	16.0 mm.
Female	134.6 mm.	220.0 mm.
Spicules—Long	0.74 mm.	0.7 mm.
Short	0.34 mm.	0.34 mm.
Eggs	45 by 0.30μ	49 to 0.50μ by 29 to 30μ

I am indebted to Dr. R. J. C. Hoeppli, Professor of Parasitology, Peiping Union Medical College, Peiping, China, for valuable guidance and for the use of his own library references; to the Rockefeller Foundation for the grant of a fellowship for the study at the School of Hygiene and Public Health, University of the Philippines, Philippine Islands, and in the Division of Parasitology, Peiping Union Medical College, 1929-30, and to the said institutions for the facilities afforded for carrying out this investigation.

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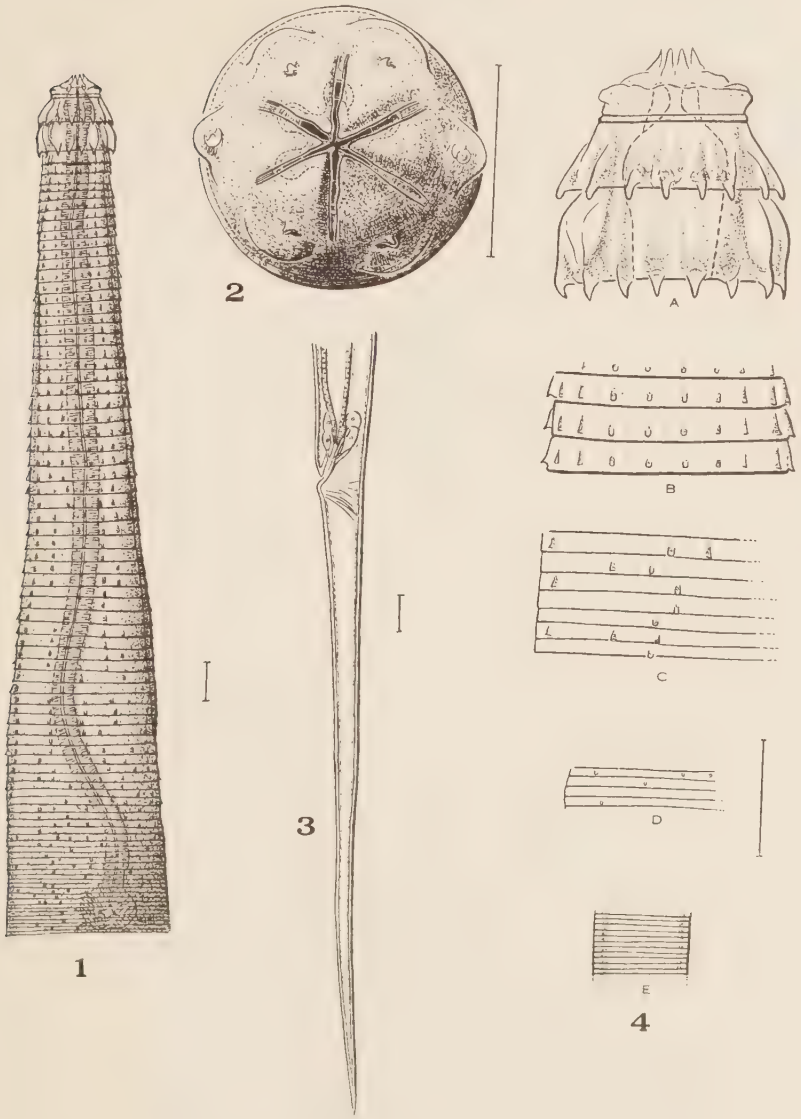


PLATE XV

Explanation of Plate XV

Hoepplius spinosus, Figs. 1-4

Fig. 1.—Female, anterior end, lateral view.

Fig. 2.—Female, anterior end, frontal view.

Fig. 3.—Female, the tail, lateral view.

Fig. 4.—Female, different regions of the cuticula: a, first two transverse striations; b, tenth-twelfth transverse striations; c, around bulb of esophagus; d, around middle of intestine; e, around tail.

The scale in all figures represents 0.1 mm.

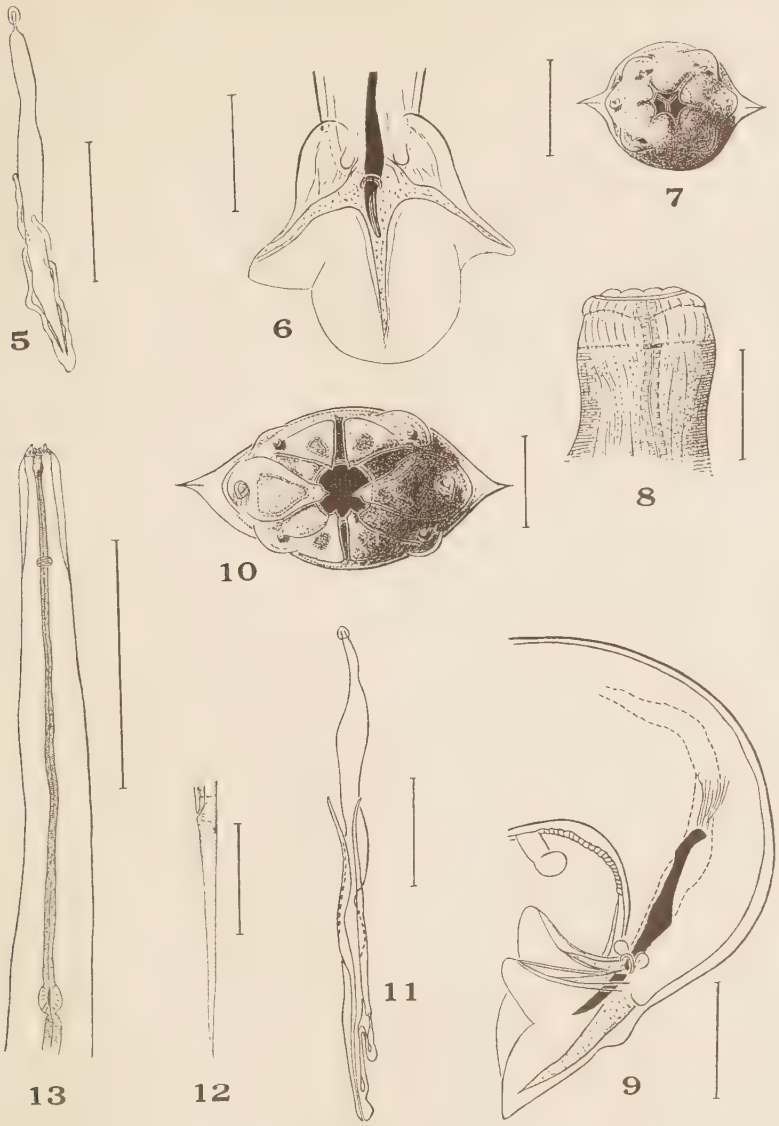


PLATE XVI

EXPLANATION OF PLATE XVI

Hoepplius spinosus, Figs. 5-9

Fig. 5.—Female, ovaries and uterus.
Fig. 6.—Male, posterior end, ventral view.
Fig. 7.—Male, anterior end, frontal view.
Fig. 8.—Male, anterior end, lateral view.
Fig. 9.—Male, posterior end, lateral view.

Hoepplius boholi, Figs. 10-13

Fig. 10.—Female, anterior end, frontal view.
Fig. 11.—Female, ovaries and uterus.
Fig. 12.—Female, tail.
Fig. 13.—Female, anterior end, lateral view.
The scale in figs. 6-10 represents 0.05 mm., in figs. 11-13, 1.0 mm

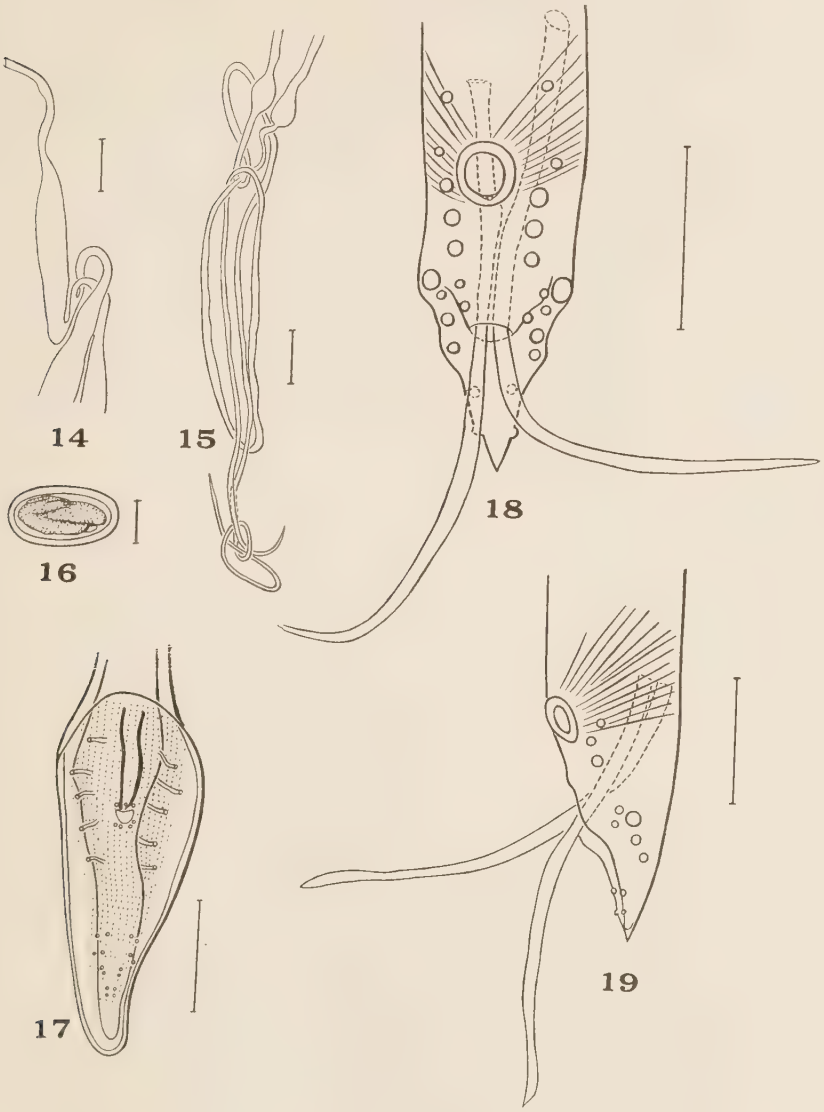


PLATE XVII

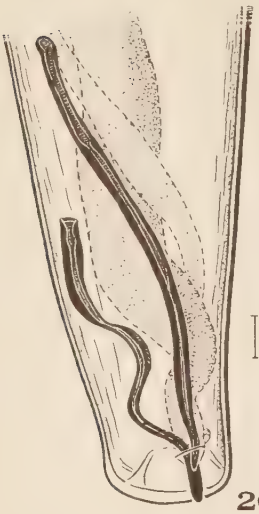
EXPLANATION OF PLATE XVII

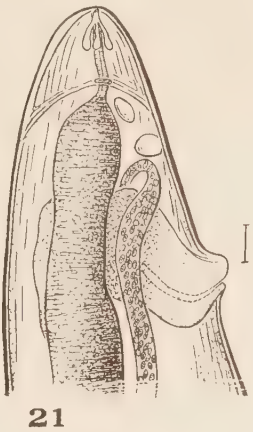
Physaloptera reevesi, Figs. 14-17

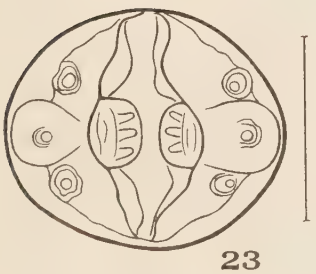
Fig. 14.—Female, junction of uteri.
Fig. 15.—Female, posterior part of uterine tubes.
Fig. 16.—Eggs.
Fig. 17.—Male, posterior end, ventral view.

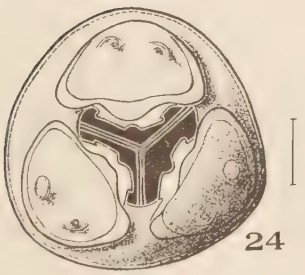
Ascaridia gcei, Figs. 18-19.

Fig. 18.—Male, posterior end, ventral view.
Fig. 19.—Male, posterior end, lateral view.
The scale in fig. 16 represents 0.02 mm., in all other figures 0.5 mm.









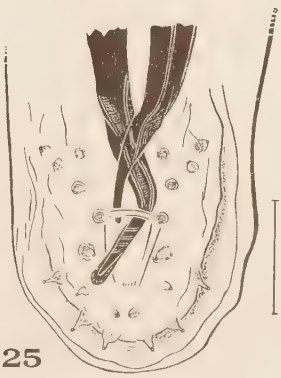


PLATE XVIII

EXPLANATION OF PLATE XVIII

Diplotriaena manipoli, Figs. 20-22.

Fig. 20.—Male, posterior end, ventral view.
Fig. 21.—Female, anterior end, lateral view.
Fig. 22.—Female, anterior end, frontal view.
Fig. 23.—*Physaloptera reevesi*, female, anterior end, frontal view.
Fig. 24.—*Ascaridia geei*, male, anterior end, frontal view.
Fig. 25.—*Serratospiculum chungi*, male, posterior end, ventral view.
The scale in all figures represents 0.1 mm.

SOCIETY PROCEEDINGS

AMERICAN SOCIETY OF PARASITOLOGISTS

Sixth Annual Meeting, Cleveland, Ohio, Dec. 30, 1930, to Jan. 1, 1931.

The annual meeting of the American Society of Parasitologists for the presentation of scientific papers was held in the Institute of Pathology of Western Reserve University, December 30 and 31, 1930, and January 1, 1931. A program made notable by an excellent group of papers was enhanced in interest by reason of joint sessions with the American Society of Tropical Medicine, which was holding the first of its triennial joint meetings with the American Society of Parasitologists. The address of the retiring president, W. W. Cort, on *Recent Investigations on the Epidemiology of Human Ascariasis* (published in full in this issue), was read before a large audience on Tuesday afternoon. It was followed by the annual tea of the Society in the library of the Institute.

The annual business meeting of the Society was held on Tuesday noon, following the annual luncheon, at the Cleveland Club, with 76 present. The report of the Treasurer, as of the close of business, December 20, 1930, was read and approved, having already been audited at a meeting of Council, December 29, 1930, as follows:

Balance forward from 1929	$ 28.61
Arrearages collected for 1929	14.00
Dues collected for 1930	436.00
Total available for fiscal year 1930	$478.61
Expenditures to December 20, 1930	452.81
Cash balance forward to 1931	$ 25.80
Advance dues and exchange collected	414.97
Total on hand, December 20, 1930	$440.77

The report of the Secretary on membership as of December 20, 1930, was read and approved as follows:

	U.S.A.	Outside U.S.A.	Total	Per Cent
Members in good standing (paid for 1930)	369	67	436	77
Former China Branch, reinstated as of 1931	1	15	16	3
Former China Branch not yet heard from	...	28	28	5
Delinquent 1 year (1930)	48	10	58	10
*Delinquent 2 years (1929 and 1930)	23	4	27	5
Total	441	124	565	100

It was announced that at the Council meeting of December 29, 1930, the following were elected as the first foreign honorary members in the Society: Émile Brumpt, France; Otto Fuhrmann, Switzerland; Akira Fujinami, Japan; Friedrich Fülleborn, Germany; G. H. F. Nuttall, England; Edoardo Perroncito, Italy; Arnold Theiler, South Africa.

The Council, as a nominating committee, proposed the following list of officers who on motion were unanimously elected:

President: W. A. Riley, University of Minnesota.

Vice-President: Asa C. Chandler, Rice Institute.

Secretary-Treasurer: Norman R. Stoll, Rockefeller Institute.

* 26 dropped by action of Council, December 29, 1930. At the same Council meeting 31 applicants were elected to active membership.

Council member, term expiring 1931 (unexpired term of W. A. Riley): L. R. Cleveland, Harvard Medical School.

Council member, term expiring 1932 (unexpired term of A. C. Chandler): H. E. Ewing, National Museum.

Council member, term expiring 1934: W. W. Cort, Johns Hopkins University; E. C. Faust, Tulane University.

Council members whose terms hold over are as follows:

Term expiring 1931: W. H. Taliaferro, University of Chicago.

Term expiring 1932: C. W. Stiles, National Institute of Health.

Term expiring 1933: W. B. Herms, University of California; B. Schwartz, U. S. Department of Agriculture.

NORMAN R. STOLL, *Secretary-Treasurer.*

BOOK REVIEWS

THE AFRICAN REPUBLIC OF LIBERIA AND THE BELGIAN CONGO. Edited by RICHARD P. STRONG. 2 vols., 1064 pp., 9 maps, 476 illustrations, 28 text figs. Cambridge: Harvard University Press, 1930.

This report on the work of Harvard African Expedition in 1926-1927 appears in two imposing volumes which contain a wealth of material that will interest a wide circle of readers. Space is lacking for any comment on the work in Part I which deals with conditions in the Republic of Liberia in a broad and interesting manner.

Part II covers the medical and pathological investigations made in this area. These naturally include items of great importance to the student of parasitology. Malaria, yellow fever, and schistosomiasis are discussed briefly. Filariasis which is treated at length, while moderately prevalent and widely distributed, is nowhere extensive. The Guinea worm reported previously to be very common is in fact rare, as only one case was seen and other reports were thought to be due to visitors coming from Central Africa. Infection with Onchocerca was present at an altitude of 900 feet and over. The expedition was successful in finding the breeding place of the black fly responsible for its transmission. A careful study was made of the developmental stages of this fly and the tumors produced by the parasite which were obtained at various places and later subject to intensive examinations. The pathology of these tumors is treated at length and illustrated by several plates including one in color. Evidence as secured indicates that the disease in West Africa is not identical with that found in Guatemala.

Some interesting observations are recorded in the section on African sleeping sickness and the possible relations to it of the trypanosomes of monkeys and other mammals.

A large section is devoted to the parasitic infections of various animals and the possible relation of these to human parasites. A number of infections with hematozoa were observed in monkeys and helminthic infections were found in the same hosts. Some attention was paid to the parasites of reptiles and other small animals but the major part of the work was done on wild game; from findings in these hosts the book gives extensive and interesting data regarding a good many parasites. The further notes and technical descriptions of some of the helminths collected by the expedition form the contents of a special chapter by J. H. Sandground. The volume includes also a section on special protozoological studies of the blood by Max Theiler as well as briefer items on a large number of other problems that were studied.

The second volume opens with chapters by various authors discussing the mammals, birds, reptiles and amphibians of the region traversed. The largest part of this volume is devoted to medical and economic entomology by J. Bequart. His studies, often referred to in the earlier sections of this work, include here more detailed and technical presentations of the species collected. While the forms treated are limited to those primarily of medical or economic significance, even they are too numerous to permit of special mention here. The wealth of material discussed in this section makes it of marked value to students of the region and workers in the field of medical entomology.

The work is splendidly printed and superbly illustrated. It reflects great credit upon the leadership and the members of the expedition and as a contribution from the Department of Tropical Medicine and the Institute of Tropical Biology and Medicine of Harvard University it will stand as permanent evidence of a noteworthy achievement of that institution.

PROBLEMS AND METHODS OF RESEARCH IN PROTOZOOLOGY. By ROBERT HEGNER and JUSTIN ANDREWS. 532 pages, 28 figs., 15 tables. The Macmillan Company, New York.

With the aid of twenty-five fellow contributors, well-known for their work in special parts of the field, the authors have sought to gather into a single volume material yet unpublished or so widely scattered that it was in truth not available. The recent start and rapid growth of protozoology have made difficult the task of gaining knowledge of the problems demanding solution. A review even by titles of the 42 chapters in the book would exceed the reasonable limits of space, but a few items will suffice to show the trend of the various contributions: The Species of Human Amoebae, by Charles A. Kofoid; The Cultivation of Endamoeba Histolytica, by Charles F. Craig; Research Problems in the Opalinidae, by Maynard M. Metcalf; Microsporidia, by R. R. Kudo; Laboratory Methods in Malaria, by Reginald D. Manwell; The Infection and Dissection of Mosquitoes, by M. A. Barber; Serological Methods in the Study of the Protozoa, by William H. Taliaferro; Host-Parasite Relations Between Animals and Their Protozoan Parasites, by Robert Hegner; Coprozoic Protozoa, by Justin Andrews; Methods and Problems of Cross-Infection Experiments with Intestinal Protozoa of Man and of Certain Laboratory and Domestic Animals, by John F. Kessel. However, other chapters are equally important and despite its varied origins the book has a continuity of interest that is striking. The book closes with a good bibliography and its value is enhanced by two fine indexes.

LE BOUTON D'ORIENT. By GEORGES HIGOUMENAKIS. 149 pages, 33 figs. Masson & Cie., Paris, France.

From the pen of a Greek physician, familiar by contact with this disease, which though rare in western lands is frequent in Greece and in Crete, especially among infants, comes the first separate and comprehensive work on the Aleppo boil or oriental sore as it is called. Dr. Higoumenakis, trained at home with a master who had himself contributed to the study of this malady and subsequently in Paris, was well fitted to discuss the morphology and experimental handling of the organism as well as its clinical manifestations. The book is a well-rounded treatise on the subject and brings together comprehensive data on life history, mode of transmission, laboratory culture and biology of the parasite as well as on the pathology, clinical types, prognosis, prophylaxis and therapy of the disease. An extensive and particularly well organized bibliography which closes the book deserves especial commendation.

PROTOZOAN PARASITISM OF THE ALIMENTARY TRACT. By KENNETH M. LYNCH. 258 pages, 37 text figs. The Macmillan Company, New York.

The author has striven to prepare a work that will be of service to students and practitioners of medicine concerned primarily in the diagnosis, treatment and prevention of disease in man. He recognizes that to many it will appear radical, yet he may be congratulated on the success with which he has pointed out pitfalls and insisted on care and accuracy in seeking for essential features in perfecting a diagnosis. The various species are discussed in order; descriptions are in readable form and emphasis is laid on the factors most significant in practical work; prevention and treatment receive major attention. The style is lucid and the selection of material good. The reader is referred to other named sources for further details. Protozoologists will find it useful since it gives a clear picture of a phase of the subject unfamiliar to laboratory workers or overlooked by them.

NEMATOMORPHA; ACANTHOCEPHALA. By MAX RAUTHER. In Kükenthal's Handbuch der Zoologie. Leipzig, 1930.

Recently attention was called here to an earlier section of this great work, planned and begun by Professor Kükenthal. The part now in hand covers two

aberrant classes of the Nemathelminthes: V. Nematomorpha, including the Gordioidea and the Nectonematoidea, and VI. Acanthocephala. Both classes are thoroughly and critically discussed and their position in this phylum more fully justified than by previous writers. The structure, development and life history of each group is described and its taxonomy summarized.

A Dictionary of Greek and Latin Combining Forms Used in Zoological Names. By Edmund C. Jaeger. 101 pp. C. C. Thomas, Springfield, Ill.,

A useful and interesting booklet with succinct and lucid explanations of thousands of common terms, for which one can wish a wide circulation. For the elementary student the present book in attractive type and format will no doubt suffice. A few slips may be noted in passing for the sake of the expected second edition. "Entymological" is an explicable but unfortunate misprint with which to conclude the preface. *Thorax* should be included to help explain *Acrothoracica; ict- for Ictalurus;* dextr- for *ambidextrous; dyt-* does not quite mean "an inhabitant" (p. 30) but rather one who creeps into, dives into, or burrows into; *anax* and not *onax* is the word for king; but these things are trifles.

Among other records in the *Annual Report of the South African Institute for Medical Research for 1929,* it was noted that in an extended investigation of Ancylostomiasis there was a certain degree of correspondence between the skin reaction tests and the presence or absence of ova in the stools, but the correspondence was not sufficiently close to justify adoption of skin-testing as a routine method of diagnosis.

The *Instituto Biologico de Defesa Agricola e Animal* of Sao Paulo, Brazil, has published volume 3 of the *Archivos,* edited by the Director, Dr. Arthur Neiva. In a well printed and beautifully illustrated volume of 330 pages is found a score of separate papers, most of which contain material of interest to workers in the field of medical zoology.

Special attention should be called again to the *Report of the Director of Veterinary Services and Animal Industry* (Pretoria, South Africa). Volume XVI, August, 1930, includes numerous original contributions on helminthology and medical entomology that will interest parasitologists.

IN MEMORIAM

ANDREW BALFOUR (1874-1931)

In the death of Sir Andrew Balfour the field of parasitology has lost an able and distinguished leader. A year ago his health broke down from over-work and he died on January 29, 1931, at the age of 57. After graduation from the University of Edinburgh in 1894 he embarked on the practice of medicine; being especially interested in direction of hygiene, he prosecuted further studies and researches leading to a D.P.H. as well as the M.D. and was granted a gold medal in 1898 for his paper on the Toxicity of Dye Stuff and River Pollution. His work there and in the South African War led to his appointment in 1902 as Director of the Wellcome Tropical Research Laboratories at Khartoum; there he directed work which eliminated malaria from the town and made it a model as a center of health. Through the work of a floating laboratory on the Nile constructed and operated at his suggestion important studies were carried out in that region. He worked especially on protozoology and elucidated the life history of spirochetes in the tick and their relation to man and to birds. On his return to London in 1913 he founded the Wellcome Bureau of Scientific Research. One of his most important discoveries made that year on a tour of the West Indies and South America was that monkeys are the reservoir of yellow fever. During the World War and afterwards he was an advisor on tropical disease in Africa, in the Near East, and in the West Indies. The London School of Tropical Medicine founded in 1923, primarily by the contributions of the Rockefeller Foundation, called him to the position of Director and he supervised personally every detail of the construction of the buildings and the organization of the work. Doctor Balfour visited America in 1926 to deliver the dedicatory address at the opening of the Johns Hopkins School of Hygiene. On this occasion he was granted the LL.D. by Johns Hopkins and Rochester universities. His writings include a long list of important special articles on technical subjects and a series of larger works in the general field of public health and preventive medicine. He was unquestionably one of the great leaders in the study of tropical medicine and made important permanent contributions to parasitology and the relation of animals to disease.

ALCIDE RAILLIET (1852-1930)

In the death of Professor Alcide Railliet on December 25, 1930, at the age of 78 years, the field of parasitology has lost one of its best and most highly prized workers. He was trained in the national Veterinary School at Alfort from which he was graduated in 1875 with high honors. Turning his attention to science he was made professor at Alfort in 1879 and retained this position until his retirement. His well known book, *Traité de zoologie médicale et agricole,* one of the first to appear in the newly opened field of parasitology, exercised a wide spread influence on the rapid development which that field experienced and in which he was one of the prominent leaders.

Apart from this book Railliet published a large number of shorter contributions mostly in the technical publications of the time and in the transactions of scientific societies. He was collaborator in *Annales de Parasitologie Humaine et Comparée* founded by Brumpt in 1923 and contributed the first article to the initial number of this periodical which from the start assumed leadership in the field. He himself was the editor in charge of *Recueil de médecine véterinaire d'Alfort* and served as general secretary of the prominent French society of Veterinary Medicine.

Railliet's work dealt in large part with nematodes in which field he contributed to a remarkable extent towards knowledge of the structure and classification of this difficult group. In fact, his contributions may rightly be said to have inaugurated the first successful effort to unravel this confused topic. He pointed the lines of procedure along which present day work is successfully continuing toward the solution of the problems presented by this highly specialized and isolated group.